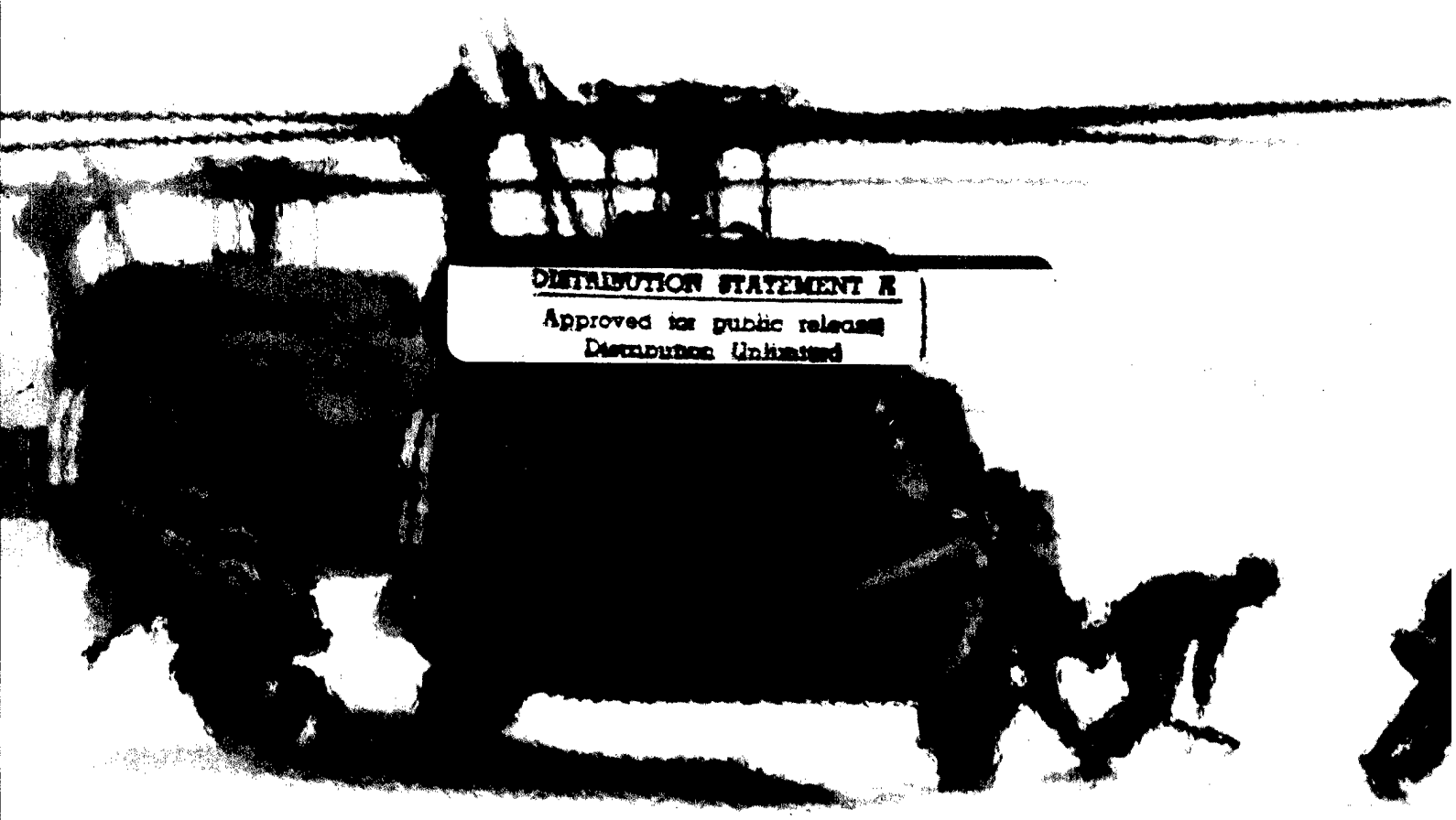
INSTITUTE FOR DEFENSE ANALYSES



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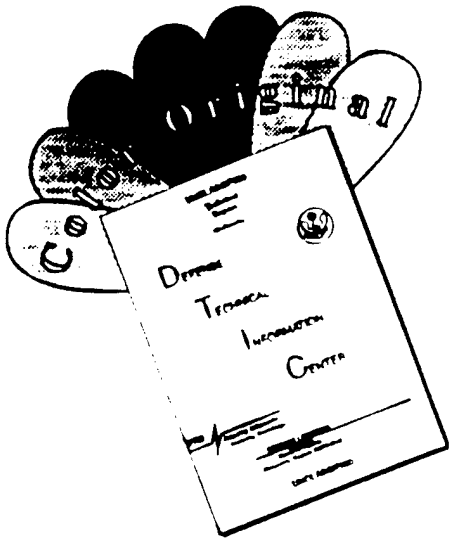

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The Institute

The primary mission of the Institute for Defense Analyses, a federally funded research and development center, is to assist the Office of the Secretary of Defense, the Joint Staff, the Unified and Specified Commands, and Defense Agencies in addressing important national security issues. IDA also works for other federal agencies, such as the Department of Justice and the National Aeronautics and Space Administration, when our skills and experience are appropriate to their uses and when the work is likely to be synergistic with that done for the Department of Defense.

Message from the President

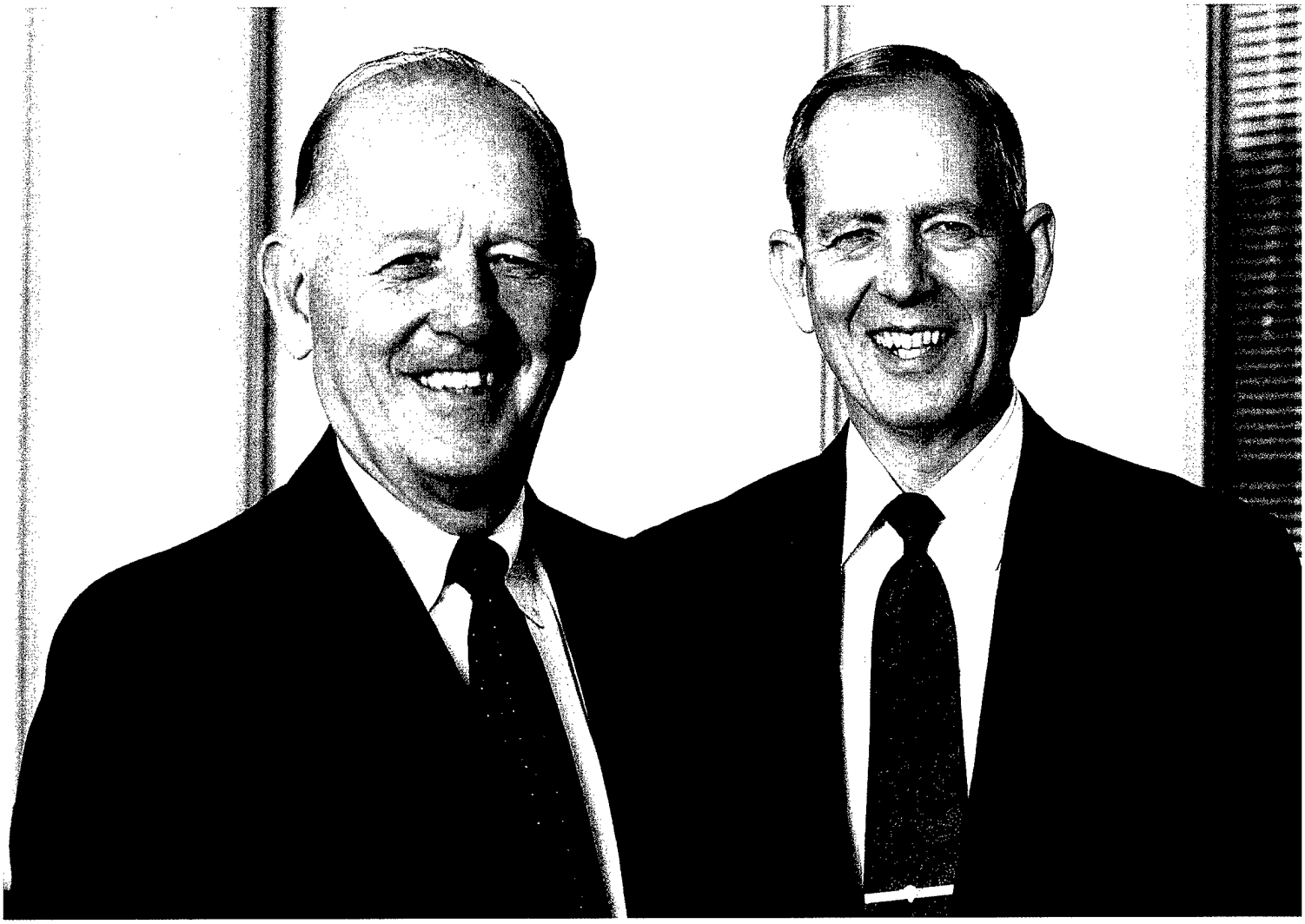
Both the successful ending of the cold war and the decisive military victory in the Persian Gulf war provide convincing evidence that past national security decisions have served the nation well. But there are new and different challenges now. While the post-cold war era has been characterized by reduced East-West tensions, there exist increased risks of major military confrontation growing out of chronic regional disputes, with the Persian Gulf war being the most striking example. And the outcome of that war—dominated as it was by superior U.S. technology, training and doctrine—will likely increase the appetites of regional powers for advanced military capabilities, reinforcing the trend towards proliferation of sophisticated equipment. As more of the science and technologies demonstrated in Desert Storm spread to the rest of the world, including countries hostile to our interests, the President and the Secretary of Defense stress the importance of continuing a strong research and development program to leave a legacy of qualitative military force superiority to future generations.

The fundamental mission of IDA was defined by the Secretary of Defense some thirty-six years ago:

> ". . . to provide comprehensive, objective, and independent analyses and evaluations . . . prepared by the ablest professional minds, and the most advanced analytical methods that can be brought to bear."

While the subject areas of vital interest to defense decision-makers have changed and the tools of analysis have evolved in ways that were not conceived when the above words assigning IDA its mission were written, there remains the need for rigorously objective analytical support to the Defense Department and other government agencies. IDAs unique experience and ability in blending in-depth expertise in technology with strategic thinking enable us to provide relevant analysis in an environment of tighter budgets and changing national needs.

The program described in the following pages includes technology assessments, systems evaluations, evaluation of strategy and the forces to implement strategies, analyses of costs and resource applications, and diverse applications and advances in the area of high performance computing that, today, underlies virtually all defense and national technological capability. In these and other activities described in detail in this report, IDA is itself adapting to the new world environment and dedicating its skills to



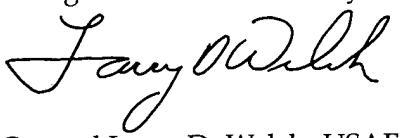
General Larry D. Welch, President (right) and Mr. Robert F. Froehlke, Chairman.

helping ensure that this nation continues to lead in those technology applications vital to our national security and welfare. Several areas of changing emphasis in our program merit special mention.

Support to test and evaluation activities has been reinforced and expanded. We are providing analytical support to the Director of Defense Research and Engineering in implementing a vigorous new emphasis in areas of science and technology that promise to maintain America's military advantage to meet future contingencies. We have established a simulation laboratory and are working with the Department of Defense to support DoD's growing ability to simulate battlefield activities and systems in variable "synthetic environments." We also are emphasizing work on the distributed computing power that makes simulation activities feasible. Our support of the National Aeronautics and Space Administration in its programs to provide both effective and economical space exploration and scientific investigation is an important new initiative for IDA, one which adds a challenging opportunity to continue IDA's dedication to quality analyses in support of major decisions affecting the allocation of national resources.

Our success in meeting the demand for thoughtful, informed and coherent analytical support for increasingly complex decisions has and continues to depend on a highly qualified group of analysts working in an environment that nurtures quality, objective, independent thinking. To reinforce the capability of this staff to carry out IDA's responsibilities, the "IDA Quality Focus Program" adds even greater emphasis to our focus on the decision-makers' needs. While IDA has always given strong attention to the quality and utility of its product, further efforts are being made under this program to enhance rapport and communication with sponsors, to continue building advanced analytical tools, and to foster even stronger reviews of our work—to assure the IDA product is one of quality, objectivity and relevance.

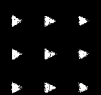
The following pages present representative highlights of IDA's work over the past year—efforts that are keeping IDA in the forefront of helping strengthen national security in this difficult and uncertain time.



General Larry D. Welch, USAF (Ret)
President

The IDA Research Program

IDA's yearly program of research is a mixture of continuing analyses that address enduring problems and new starts in response to sponsor requirements. We categorize our work into five primary areas: technology assessments, systems evaluations, force and strategy assessments, resource and support analyses, and high performance computing and communications. Overviews of each of these, with brief descriptions of representative studies, are given here.



Technology Assessments

Since the late 1950s, the Institute has undertaken studies of new technologies for application to advanced military systems. These efforts have included assessments of emerging technologies to determine their potential to meet specific military needs, evaluations of technologies incorporated in systems to determine the degree to which they have been matched and integrated with the overall system, and analyses of the status of U.S. technology for planning and policy purposes. IDA has special expertise in many technology areas, including simulation and training systems, materials, space systems, surveillance and target acquisition, observables, and information and software systems. Recent efforts in several of these areas are discussed under *Areas of Special Interest;* others are highlighted below.

Science and Technology Thrusts

At the request of Director, Defense Research and Engineering (DDR&E), IDA is helping to revitalize and refocus the Department's science and technology efforts to provide a technical weapons legacy for the future as dramatic as that our predecessors left for Desert Storm. DDR&E has established seven Thrust Panels in the areas of global surveillance, precision strike, air defense and superiority, sea control and undersea warfare, land combat vehicles, simulation, training and readiness, and technologies for affordability. Each panel is currently reviewing its area and developing a vision for the future, a taxonomy of functions, a critical analysis of the science and technology needs, and a comparative analysis of ongoing programs to determine whether a redirection of effort, a resetting of priorities, or other changes are needed. IDA is assisting DDR&E in integrating the seven perspectives into a cohesive science and technology program for the future.

Strategic Defense and its Derivatives

IDA has worked closely with the Strategic Defense Initiative Organization (SDIO) since the inception of the SDI program. As the program has matured, we have provided support to both the science and engineering sides of SDIO. The former has involved assessments of missile plume signatures, software technology, battle management and

C^3 systems, space materials, and a variety of innovative technologies. The engineering side of SDIO has depended heavily on IDA as well, primarily though the so-called Phase One Engineering Team (POET). The lessons of the SCUD in Desert Storm have provided an impetus for POET to undertake an Advanced Theater Missile Defense program; we are providing key technical leadership in that area.

Technologies for Improved Conventional Defense

The Institute continues to identify advance concepts that promise significantly improved conventional military capabilities and to assess their military utility. Our efforts emphasize risk reduction and multi-Service applications. Over this reporting period, our studies have examined millimeter wave technologies, the impact of multipath and clutter on millimeter wave target acquisition and fire control, computer-aided target recognition systems for ground combat vehicles, and laser countermeasures against infrared missiles.

Materials

A study of ceramic matrix composites (CMC) for industrial applications was undertaken at the request of DDR&E; the effort is aimed at identifying technical exchange possibilities that exist among the DoD, NASA, and the Department of Energy (DoE). DoE has established a new program for the development of ceramic matrix composites for industrial applications; these include stationary gas turbines, waste heat recuperation systems, and waste incinerators. In spite of differences in emphasis, coordination among DoD, NASA and DoE programs of mutual interest could lead to better utilization of R&D resources and to technologies that better meet DoE's technical goals. At the same time, DoE's promotion of broad industrial use of CMC technology could eventually lower CMC costs, benefiting DoD and NASA programs that draw on the same industrial base.

Interest in the use of armor ceramics in land-based and airborne vehicles is increasing because of their ballistic performance and their light weight. IDA is advising DARPA on how advances in ceramics composition and processing can be incorporated more easily into armor

applications, and on how to better evaluate the performance of such materials in light of the proposed standardized test methods to be employed by government and industry.

The Software Environment

Standardized commercial Software Engineering Environments (SEEs), particularly those based in the Ada programming language, are foreseen as the next major step toward achieving the goals of increased productivity, reliability, maintainability, and portability for DoD software systems. IDA continues its extensive role in supporting DoD and NATO sponsors by participating in the development of appropriate standards and by analyzing of specific technical issues.

IDA also supports the Ada Joint Program Office through participation in an international research and development project on the Ada Programming Support Environment (APSE). This project, involving several NATO nations, aims to cooperatively produce, evaluate, and demonstrate an APSE based on U.S. military standards and hosted on two different computer architectures. IDA is building enabling tools, assisting in integrating the APSE on the first architecture, and leading the APSE integration effort on the second architecture, which is located at IDA. We also are helping to develop the next generation APSE interface technology.

Export Control

Since May 1990, when the President proposed a substantial liberalization of export controls, the continuing changes in the Soviet Union and Eastern Europe have necessitated further policy revisions concerning the identification and control of militarily critical technologies. These policy revisions are being reflected in the complete review, restructuring, and rewriting of the Militarily Critical Technologies List, and development of technical proposals for a completely revised Coordinating Committee (COCOM) list. The initial round of COCOM negotiations on the revised list was completed in July 1991 after some 39 technical negotiating sessions in which IDA staff participated as technical advisors.

Systems Evaluations

A central mission of IDA since its founding has been the evaluation of weapon systems and other military equipment at all stages of development—from paper concept to full-scale operational testing. This section discusses IDA's systems evaluation activities, excluding operational test and evaluation. Our contributions to the latter are discussed under the heading *Areas of Special Interest*.

Systems evaluations, which typically support development or acquisition decisions, involve assessments of the performance of systems under a variety of conditions. Related issues of technological risk and cost often are addressed as well. Our program of studies, examples of which are given below, covers strategic systems; tactical systems for naval warfare, land warfare, and air warfare; command, control and communications systems; and systems dealing with information and software.

Strategic Systems

Assessment of the Capabilities of the B-1B Aircraft

The recent cutback in the procurement of B-2 bombers has placed increased attention on programs to improve the performance of the existing 96 B-1Bs, which will represent the largest element of the U.S. penetrating bomber force for years to come. Responding to direction contained in the National Defense Authorization Act for FY 1990-1991, this study examined the capabilities of the B-1B aircraft to penetrate Soviet air defenses in a nuclear war in the year 2000. The assessment was based on the results of the Air Force test program of the bomber's ALQ-161 defensive avionics system. The B-1B uses the ALQ-161 to detect, identify, and avoid—or degrade through the use of countermeasures—enemy threats it may encounter. The study compared aircraft survivability and the numbers of weapons that could be delivered, assuming the B-1Bs were outfitted with current and improved versions of the ALQ-161 and with other enhancement options. A wide range of threat and operational assumptions were considered.

Future Strategic Submarine System Study

This analysis of future strategic submarine systems identifies current and emerging technological opportunities that could offer high

payoff for upgrading and possibly replacing the current Trident systems—the submarine, the missile, and the command, control and communications—to accommodate the mission flexibility dictated by the ongoing changes in the global political and military balance. The findings of this study offer approaches for extending the life of strategic submarines beyond the nominal 30 years, ways to manage acoustic and other signatures, recommendations for more efficient manufacture, and suggestions for improving strategic submarine R&D through cooperative efforts with the tactical submarine research community.

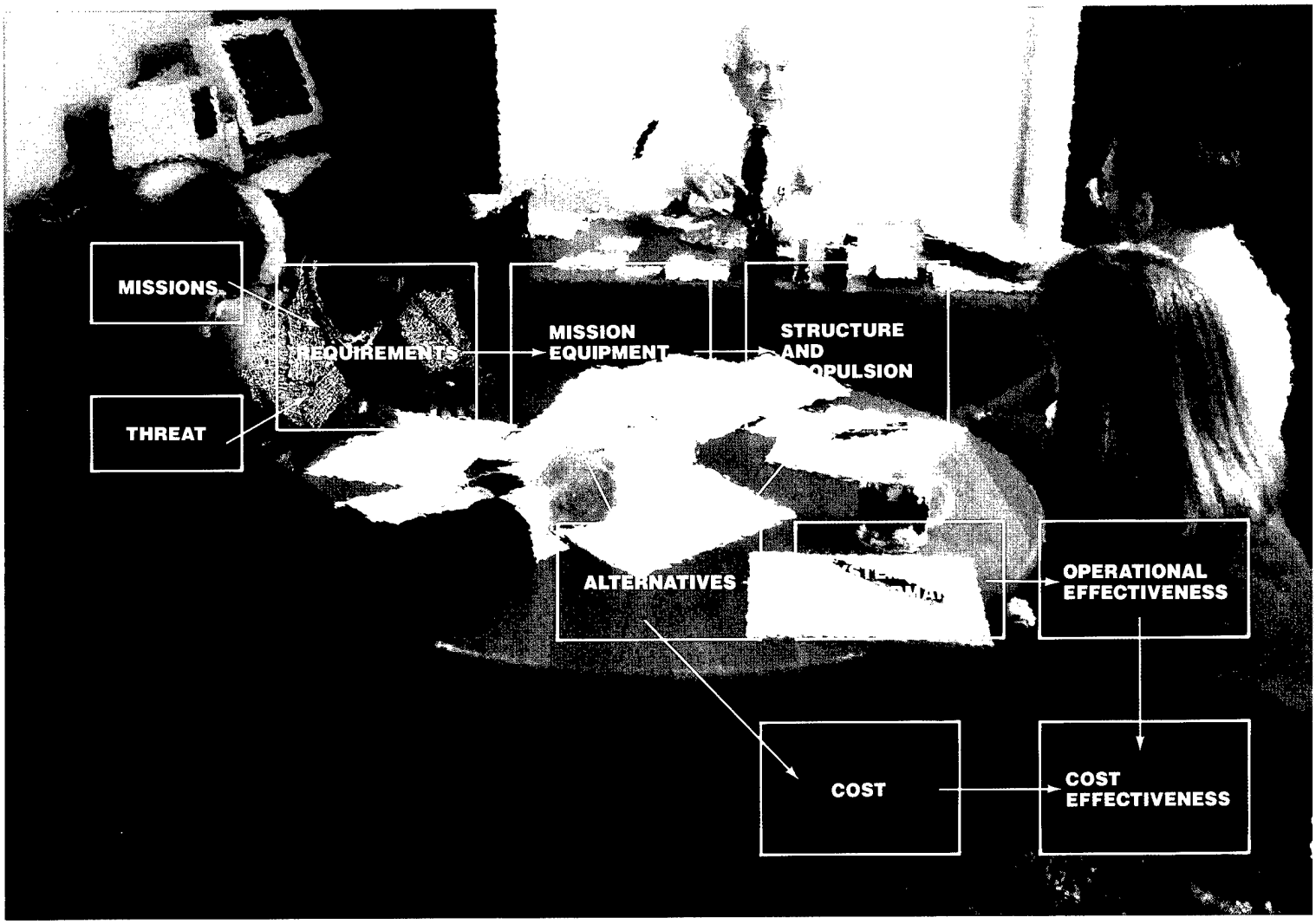
Tactical Systems

Options for Surface-to-Air Systems

This study projects the effectiveness and cost of concepts for a follow-on to the medium-range Hawk surface-to-air missile system. The alternatives include a variety of subsystem design options: one- and two-dimensional array radars, various guidance, control and propulsion techniques, and X- and K-band radar missile seekers. Important capability issues involve the effectiveness of the alternatives against tactical ballistic missiles, their ability to counter enemy electronic countermeasures, and their vulnerability to anti-radiation homing weapons. The overall performance of the options is compared in a variety of possible combat scenarios. Estimates of system costs round out the evaluation.

Alternative Technologies for the Nonacoustic Detection of Submarines

The dramatic acoustic quieting of Soviet submarines combined with the proliferation of quiet diesel submarines throughout the Third World have led to renewed interest in nonacoustic techniques for detecting submarines. IDA is conducting a broadly scoped assessment of the capabilities and costs of a range of nonacoustic detection technologies. Among the concepts examined are techniques to detect a submarine's electromagnetic effects (such as perturbation of the earth's magnetic field), its optical effects (such as its reflection of the light emitted by a blue-green laser), its hydrodynamic effects (such as its underwater wake and the effects of its passage on the ocean's surface), and the chemical, nuclear, and thermal residues it leaves behind. For



Interdisciplinary teams focus on in-depth analyses of system capabilities.

those concepts that appear feasible technologically, the study is estimating their potential performance against a spectrum of submarine threats and is determining the cost of developing and operating detection systems based on those concepts. To identify performance uncertainties, the study is examining a wide range of geographical locations and tactical settings. The results will aid OSD in setting priorities for research funding.

Command, Control and Communications (C^3)

Joint Tactical C^3 Architecture

The Joint Tactical C^3 Agency is responsible for developing and maintaining the joint tactical C^3 architecture, which consists of several functional segments covering different aspects of joint operations. In 1987, IDA created the first of the functional architectures, which covered air defense and airspace control in a combat zone. This architecture also served as a standard for subsequent work in this area. IDA developed four more architectures that addressed fire support, special operations, air operations and, most recently, control of operations in a joint task force (JTF). The JTF architecture focused on the C^2 needs of JTF headquarters and its Service components, and in that sense it integrated all of the other functional architectures.

Each architecture summarizes joint tactical C^3 interface requirements and provides interconnectivity diagrams, tables, and matrices that depict which C^2 elements and systems must exchange information in a joint operational environment. The architectures also include descriptions of baseline C^3 systems, identify C^3 problems and issues in joint operations, and provide recommendations for correcting C^3 deficiencies and shortfalls. All of the previous IDA-developed architectures have been validated by the JCS and approved by the ASD(C^3I); the latest architecture—for JTF command and control—is in the process of validation. The ASD has directed that the validated architectures serve as authoritative guidance for program planning, that new or modified C^3 systems be measured against the architectures for interoperability compliance, and that the concepts, interface exchange

requirements, and C^2 relationships identified in the architectures be reflected in JCS doctrinal publications.

Computer Aids for JTIDS Joint Network Design and Management

The Joint Tactical Information Distribution System (JTIDS) is a computer-controlled communications system designed primarily for digital data. JTIDS is highly resistant to jamming or interception and concurrently can accommodate many distinct sets of users on different nets. Each terminal's configuration and its participation in the resulting networks are controlled by technical parameters, which the user can set to adapt the system to a specific operational environment—for example, to the anticipated jamming level. Each Service is pursuing its own approach to JTIDS network and management. Coordinating the parameters among all users is critical, and it is particularly difficult in joint operations where both Service-unique and joint operational requirements must be accommodated. The Joint Staff asked IDA to examine ways to assist in planning for the implementation of JTIDS in joint operations. The study recommended the development of computer aids for the design and management of joint networks, rather than jointly developed computer aids that might satisfy two or more Services' needs individually. The development of such computer aids would allow improved network design for Joint Force Commanders.

Information and Software

Integrity in Computer and Automated Information Systems

For several years, IDA has been examining computer security problems for the National Security Agency. One recent project focused on integrity issues. Integrity in computer and automated information systems requires that these systems protect themselves and their data from unauthorized and inappropriate actions, while performing in accordance with user requirements. It also is expected that internal data and all transformations of that data maintain a correct, complete, and consistent correspondence to what the data represent externally. This study developed a framework for examining integrity, analyzed manual

and automated mechanisms that affect integrity, and examined models and studies that suggest ways to implement integrity controls. The study concluded that it is possible to begin standardizing integrity properties of systems, that assessments of integrity could be accomplished concurrently with standardization, and that these efforts could be mutually supporting.

Interoperability Decision Support System (IDSS)

The IDSS is an information system designed to provide a low cost computer network for selected defense applications. The system was developed initially to help planners and system designers exchange information concerning the interoperability of NATO's battlefield computer systems. For this and related applications, IDSS currently includes several networks, which are generally on-line 24 hours a day, with worldwide telecommunications access. There are more than 800 users located in 23 countries.

IDSS software, developed by IDA, provides the system functions such as security, E-mail, document coordination and system management, as well as the means for accessing a number of databases. Organizations can customize the system to their needs by adding their own programs, which run inside the IDSS security shell. In fact, several other government organizations, with IDA's help, have set up and are operating their own IDSS systems.

Force and Strategy Assessments

The scope of IDA's work ranges from detailed examinations of phenomenology to broadly scoped and integrated evaluations of how well military capability conforms to national security strategy. We refer to these latter analyses as force and strategy assessments, and they generally can be partitioned into three categories.

Force Assessments

Force assessments examine questions about the overall composition of U.S. forces, that is, the balance among ground, air, and land forces and between active and reserve units. Typically, these studies assess the performance of alternative force mixes, under a variety of measures of military effectiveness, in a number of postulated scenarios. In the past, force assessment studies have examined primarily U.S.-versus-Soviet questions, such as the effectiveness of Follow-on Force Attack in the European theater. More recently, the focus has shifted to other theaters, and IDA has looked at issues such as the potential effects of chemical weapons in Southwest Asia and assessments of operational plans for Desert Storm. Two studies in the area are briefly discussed below.

Net Assessment of New Weapons Technologies

The potential effectiveness of a new weapons technology often is misperceived for two primary reasons: the prospective users view the technology as a means for better implementing a fixed doctrine that has not been adapted to the new technology, and the reactions of potential enemies are not fully taken into account. For the Office of the Director for Net Assessment, IDA is analyzing promising new reconnaissance and strike systems (such as JSTARS and ATACMS) in a way that explicitly accounts for the new doctrinal and organizational possibilities created by these technologies, both for ourselves and our opponents. We are building this effort on the analytical foundations established by the Variable Force eMployment (VFM) methodology developed for this purpose under IDA Central Research.

Non-Strategic Nuclear Forces

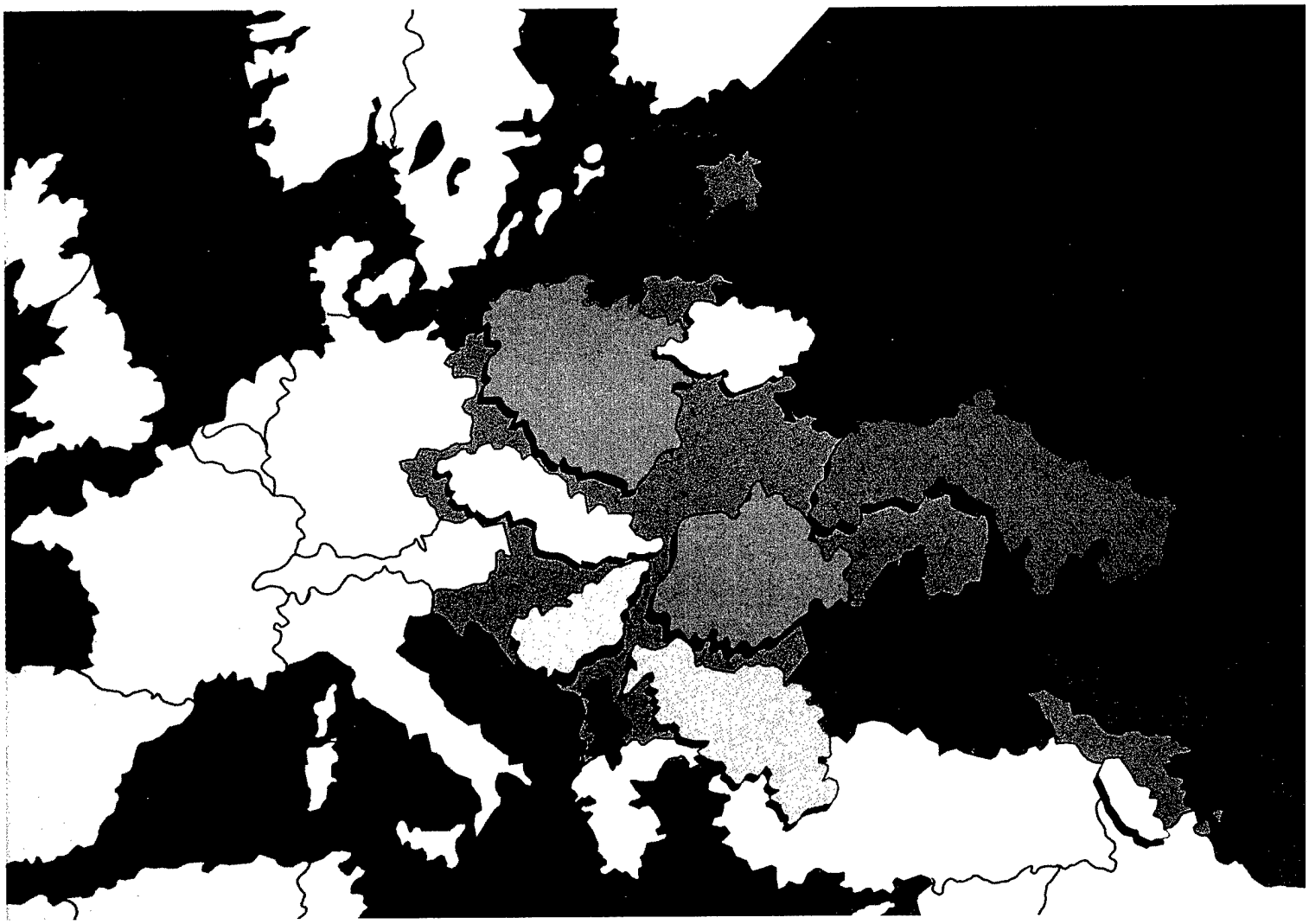
In light of changes in the nuclear threat faced by NATO in Europe, as well as the proliferation of weapons of mass destruction in the Third World, we are exploring the future roles for non-strategic nuclear forces (NSNF). Rather than direct deterrence of warfare in Europe, the primary European role of NSNF seems to be shifting toward reassurance of NATO allies during the evolution under way in the East. Non-European roles also are under investigation. Initial analyses indicate that a well structured non-strategic nuclear force can perform likely future roles adequately with far fewer nuclear weapons than currently possessed by the U.S. and our NATO allies.

Defense Strategy and Policy

Force assessments examine *how* goals might be achieved, while defense strategy and policy efforts look at *what* goals might usefully be set. Studies often address problems within a regional or topical context, such as an analysis of the implications for the Soviet military of changes in Soviet demographics, or examinations of the implications of alternative U.S. policies for regions such as the Mediterranean, the Iberian Peninsula and Latin America. These evaluations combine historical reviews with examinations of current and projected political/ military dynamics to evaluate alternative courses of action by which the U.S. military could influence events in directions favorable to U.S. national security interests. Issues pertaining to arms control, another aspect of U.S. policy affecting the size and structure of certain components of military forces, also fall into this category.

Arms Control Verification Analysis

The adequate monitoring of arms control treaties is essential if these agreements are to enhance U.S. national security. To determine what constitutes "adequate" monitoring requires an understanding of both the effectiveness and costs of monitoring systems and procedures. IDA has performed analyses of the resources needed to verify the Strategic Arms Reduction Treaty, the Conventional Forces in Europe Treaty, the Chemical Weapons Convention, and several nuclear test treaties. These analyses have assisted the cognizant offices in evaluating



Force and strategy assessments include evaluations of the dramatic political changes in Europe and their effects on force structures in the region.

proposed treaty provisions as well as in implementing treaties once they are ratified. To address the effectiveness side of treaty monitoring, IDA is developing methodologies to determine how well treaty inspection provisions contribute to monitoring goals.

IDA also works with the international arms control monitoring community through its leadership of analytical activities sponsored by the NATO Defense Research Group—a body established to foster alliance cooperation on technical and scientific issues related to defense and national security. In this reporting period, we have directed analytical efforts examining potential technological enhancements of multinational agreements and how best to verify the Conventional Forces in Europe Treaty within the constraints of protocols.

Methodology Development

Methodology development is the creation of analytical tools needed for the types of assessments discussed above. IDA prides itself on its ability to provide quantitative insight into complicated problems. Often this insight comes from computerized models and simulations developed specifically for this end. Because the issues addressed change from year to year, methodology development is an ongoing activity. Among recent developments are the expansion of the TACWAR theater combat model to address biological warfare, the expansion of our Janus simulation facility, and improvements in our ability to assess C^3.

C^3 Modeling Improvements

Assessing the impact of C^3 on combat effectiveness is particularly challenging, and one of the tools that IDA has been developing to address this problem is the C^3 Evaluation (C^3 EVAL) Model. During this reporting period, both OSD and the Joint Staff have asked to IDA to explore how the C^3 EVAL model could be applied to specific C^3 problems. For the Joint Staff, the focus is on providing tools for their analysts that will provide them with simplified model control and input. For OSD, IDA is modifying the model to include details of the communications and command postprocessing systems important to assessments of the Army Tactical Command and Control System.

Resource and Support Analyses

The efficient utilization of available resources is a central concern of the Department of Defense. Accordingly, a substantial component of IDA's work deals with the costs of defense systems and forces, the processes by which acquisition programs are managed, and the supporting infrastructure needed to maintain effective and ready forces. IDA's studies in this area have examined how to prepare the defense industrial base for mobilization and, if needed, for reconstitution of forces; what management initiatives and other techniques can lead to acquisition programs that meet their schedule and cost objectives; and how best to train military personnel. IDA has also developed a model for desktop computers that rapidly estimates the costs of alternative DoD force postures. The following is a sampling of recent resource and support studies.

Defense Program Projection

The Defense Program Projection identifies baseline forces, acquisition programs and major support functions out to the year 2000. This official, long-term financial projection is prepared by the Office of the Secretary of Defense to support preparation of the Defense Program Guidance and to facilitate long-range investment planning. The computer models used to project baseline forces, estimate associated costs, and analyze alternatives were developed and implemented by IDA.

Costs of Force Structures and Policies

IDA has assisted the Defense Department in estimating the cost savings from reductions in force structure and from shifts of missions from the active to the reserve component. A taxonomy was developed that separately addressed direct unit costs, infrastructure costs and transition costs. Particular attention was paid to the infrastructure cost implications of force structure changes. Estimates of the extent to which infrastructure (e.g., base operations, central training, and central logistics) can be expected to vary with combat force structure were made on the basis of historical experience. These estimates represent a vital step toward better planning in the current fiscal environment.

Reconstitution Studies

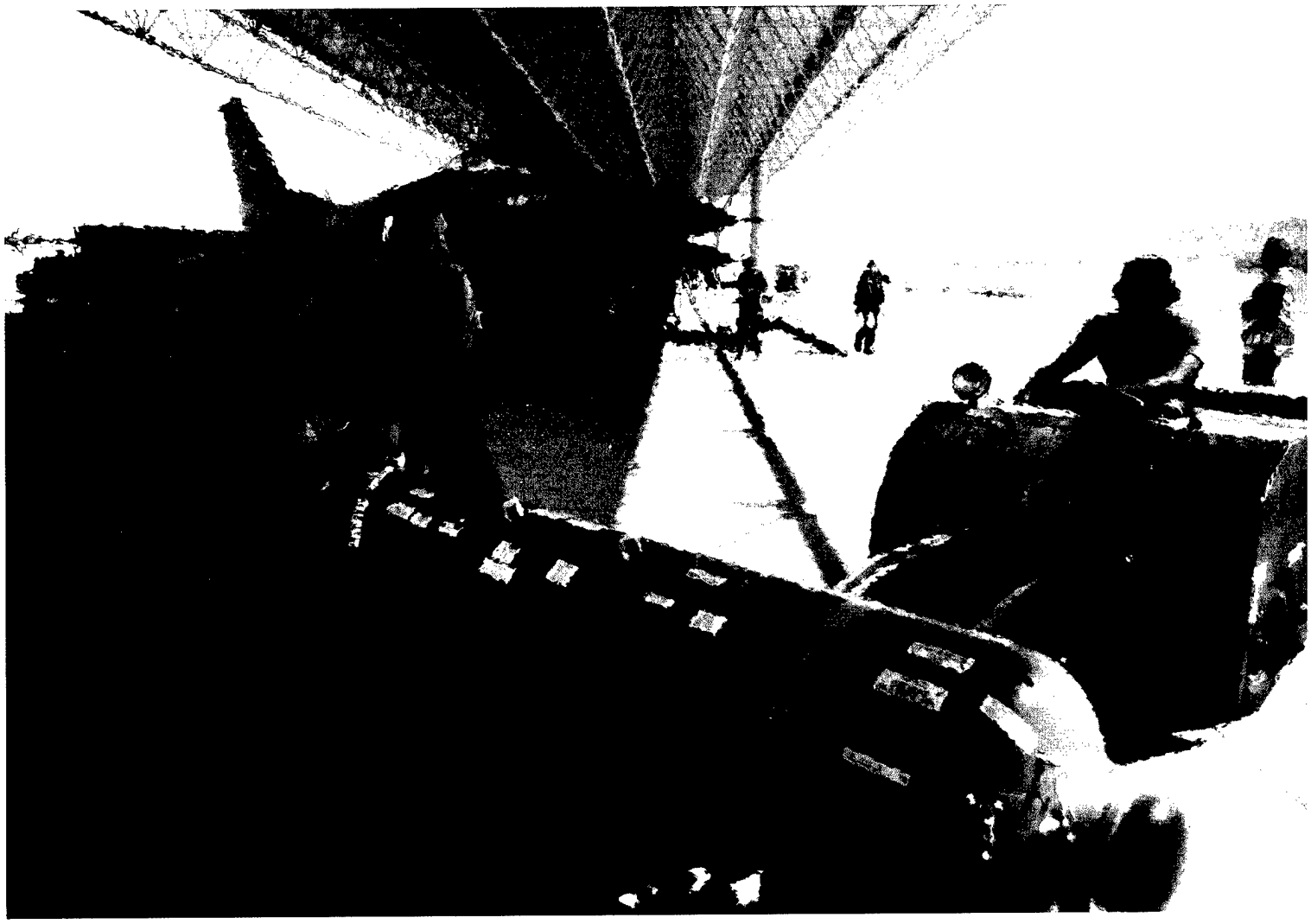
Force reconstitution is a new element of the National Military Strategy. It provides a hedge against the emergence of threats beyond the capabilities of currently planned forces. Reconstitution capability, properly implemented, would allow the U.S. to expand its defensive capability faster than any nation or coalition could build an offensive threat. Several IDA studies examine reconstitution issues associated with European defense, industrial capabilities, manpower and force management alternatives, and the implications of reconstitution for managing research and development and acquisition.

Assessing the Effectiveness of Acquisition Initiatives

IDA examined 89 weapons system acquisition programs to determine which management techniques have been effective in limiting cost growth and schedule slip. Prototyping, multi-year procurement, and contract incentives were found to be effective, and fixed-price development contracts were found to be ineffective. Design-to-cost was found to be effective when applied early. IDA recommended increased management attention be given tactical munitions programs and electronics/avionics programs, which had the worst cost and schedule records of any program type.

Economic Analyses of Defense Aircraft Manufacturers

DoD procurement regulations determine the profits that contractors can earn from manufacturing weapon systems. These regulations also provide incentives for contractors to organize their manufacturing processes in particular ways to accommodate potential wartime demands. One such incentive is the facilities capital markup, which is paid at final delivery based on the capital intensity of the manufacturing process. Our staff analyzed financial data from four aircraft manufacturers to investigate industry response to the facilities capital markup. This analysis demonstrated a strong impact of changes in the markup rate on such indicators as capital to labor ratios. DoD markup rates have succeeded in bringing capital intensity in the defense sector up to parity with levels observed in the commercial sector. As a



IDA has examined the relationship between logistic requirements and operational performance for weapons such as the F-16.

result, the defense sector is in a much stronger position to support wartime demands.

Computer-Aided Acquisition and Logistic Support—Human System Components

Computer-aided Acquisition and Logistic Support (CALS) is a DoD and industry initiative to move away from an existing paper-intensive acquisition and logistic process to a highly automated, integrated electronic operation for acquisition programs. One of IDA's activities in support of this program is to see that human needs are considered in the evolving CALS system. Initially, we focused on training and training systems; subsequent efforts were expanded to include such factors as safety, health hazard prevention, and human factors engineering. Our findings contributed to four products: an architecture integrating human aspects into the CALS process, a data dictionary containing the data elements pertaining to these human aspects, a compilation of databases of human aspects, and a report of the impact of the integration of human factors into the CALS process.

Industrial Mobilization Studies

The Department of Defense is working to improve its processes for mobilization planning and execution. Accordingly, at the request of the Office of the Under Secretary for Policy, IDA is helping develop a Graduated Mobilization Response Framework, which involves the development of packages of options for mobilizing industry, manpower, and transportation. These packages can be differentially combined to facilitate graduated logistic escalation to meet evolving security situations.

IDA also supports the Joint Staff through development of the Joint Industrial Mobilization Planning Process, which is a set of computerized tools that permits the Joint Staff to compare a planning scenario's industrial requirements against inventories and projected emergency production capacities. These tools currently are used in exercises, wargames, and planning analyses and, in the event of a crisis, would support the DoD's execution of reconstitution plans.

Military Manpower Issues

Some aspects of manpower, personnel and training policy are based more on historical precedent than on explicit analyses of how to get the most readiness out of the money the Defense Department spends on people. IDA was asked to review policies and practices related to the level of personnel experience, personnel movement, the timing of training, lateral entry, individual training technology, and the use of simulators in unit training. Recommendations included elimination of some billets for inexperienced reserve personnel, the use of more experienced crews on some ships, greater use of computer-based instructional techniques, and increased reliance on simulators. Places where additional evidence is needed to guide effective policy making were identified. Some of the initiatives that IDA suggested are being actively pursued by the Department.

High Performance Computing and Communications

Since the late 1950s, the National Security Agency has relied on IDA for state-of-the-art research in disciplines fundamental to its mission. The nature of IDA's support has evolved as the Agency's needs have changed. Beginning in 1958 with the Communications Research Division (reorganized in 1991 into the Centers for Communications Research in Princeton, New Jersey and La Jolla, California), IDA mathematicians have provided fundamental insights into the two chief tasks facing the cryptologists of the NSA—cryptology and cryptanalysis. In recent years, as communications technology throughout the world has become more complex, the NSA requested that IDA expand into new areas, including speech and signals analysis.

To allow the NSA to take advantage of the rapid development in computer technology, particularly in parallel processing, the Agency once again turned to IDA. In response, IDA established the Supercomputing Research Center in Bowie, Maryland. Here, IDA computer scientists and other researchers construct prototype processors and develop operating systems, compilers, languages and algorithms that can lead to hardware and software solutions to NSA's computing requirements.

Although much of the work of both the Centers for Communications Research and the Supercomputing Research Center is classified, a few examples of recent work at the latter are discussed below.

SPLASH

SPLASH is a reconfigurable computer and associated software. Programmed using the Logic Description Generator language, SPLASH provides very high speed performance for specific applications. Using 32 electrically programmable gate arrays, the processor provides the user with over 250,000 programmable logic blocks to be focused on the computational problem at hand. With a clock speed of up to 32 megahertz and an architecture that is unique to each application, the system has found numerous opportunities to offer both cost effective improvements and increases in performance beyond the traditional computational capabilities available. In addition to DoD applications,

SPLASH is in use at the National Institutes of Health for DNA pattern matching and is being programmed for an image processing application at NASA.

PETASYS

PETASYS implements an evaluation prototype of "processing in memory" architecture. By combining massively parallel computation and conventional scalar computation through the use of custom memory chips that incorporate intrinsic computational capability, we are aiming at achieving a mix of the high performance associated with massively parallel processing with the flexibility of scalar machines. The ability to switch from parallel to scalar mode on an instruction-by-instruction basis should result in a system that is not bounded by Amdahl's law, which describes why most massively parallel machines are currently effective only for the relatively few problems that conform to their system architecture.

H-Net

H-Net is a testbed for evaluation of a new intracomputer switch. Multiprocessor computer systems frequently are limited by their inability to communicate data rapidly from one processor to another or to memory. Extensive simulation indicates that the approach used in the H-Net switch—"desperation routing"—will achieve high throughput without the appearance of so-called "hot spots" that have plagued predecessor networks. Under normal circumstances, each message is delivered to a new node every cycle and, as a result, a message generally advances toward its destination. However, if resources are not available, then, "in desperation," the message will be routed through an indirect path. The testbed also will be used to evaluate distributed computing software aimed at achieving capability equivalent to multiple Crays from a system consisting of 64 microprocessors.

PASSWORK and Corner Turning

The PASSWORK software suite provides an application programmer an idealized massively parallel machine simulation on conventional systems ranging from workstations through

supercomputers. PASSWORK allows research into the applicability of problems for massively parallel machines before hardware development and acquisition. Further, because many problems include significant sequential portions in addition to the parallel parts of their computation, PASSWORK simulation on a large-scale computer is competitive with execution on a massively parallel computer for some applications.

Corner Turning is the process that transposes a bit array for easy access on pipelined vector computers. A vector functional unit for Corner Turning was invented at IDA's Supercomputing Research Center and a patent has been applied for. One company has implemented Corner Turning on a supercomputer now being marketed. When used in conjunction with PASSWORK, Corner Turning further improves the capability for the simulation of massively parallel computation.

Programming Languages

The Data Parallel Bit-serial C (DBC) language designed and implemented at IDA's Supercomputing Research Center is an extension of "C" that supports single-instruction-multiple-data (SIMP) parallel programming. Operational for only a few months, the language and compiler have proven both easy to use and effective. Because this language allows the user to take full advantage of the bit-level parallelism offered on the Connection Machine, some programs for this computer run at virtually the same speed as they would had they been implemented in assembly language. The compiler also will be used to generate code for the PETASYS prototype discussed above.

Eigensolver

A "divide and conquer" approach to the eigenvalue problem is being implemented for use on multi-instruction-multiple-data (MIMD) parallel processing systems. Careful attention to issues of numerical analysis has produced a prototype solver with accuracy, stability, and speed that is competitive with conventional systems and that will work efficiently on a parallel system. IDA's efforts on a fully parallel implementation of this technique is expected to utilize efficiently the resources of parallel processing systems.

Areas of Special Interest

While continuing to focus on important issues in areas of long-standing expertise, IDA's research program also must evolve in response to the changing needs and priorities of our sponsors. We have chosen here to highlight six areas of special interest; all received increased research emphasis in 1991. They exemplify our dedication to strengthening and adjusting our research activities to ensure that we continue to fulfill the mission assigned to us by the Secretary of Defense when IDA was established.

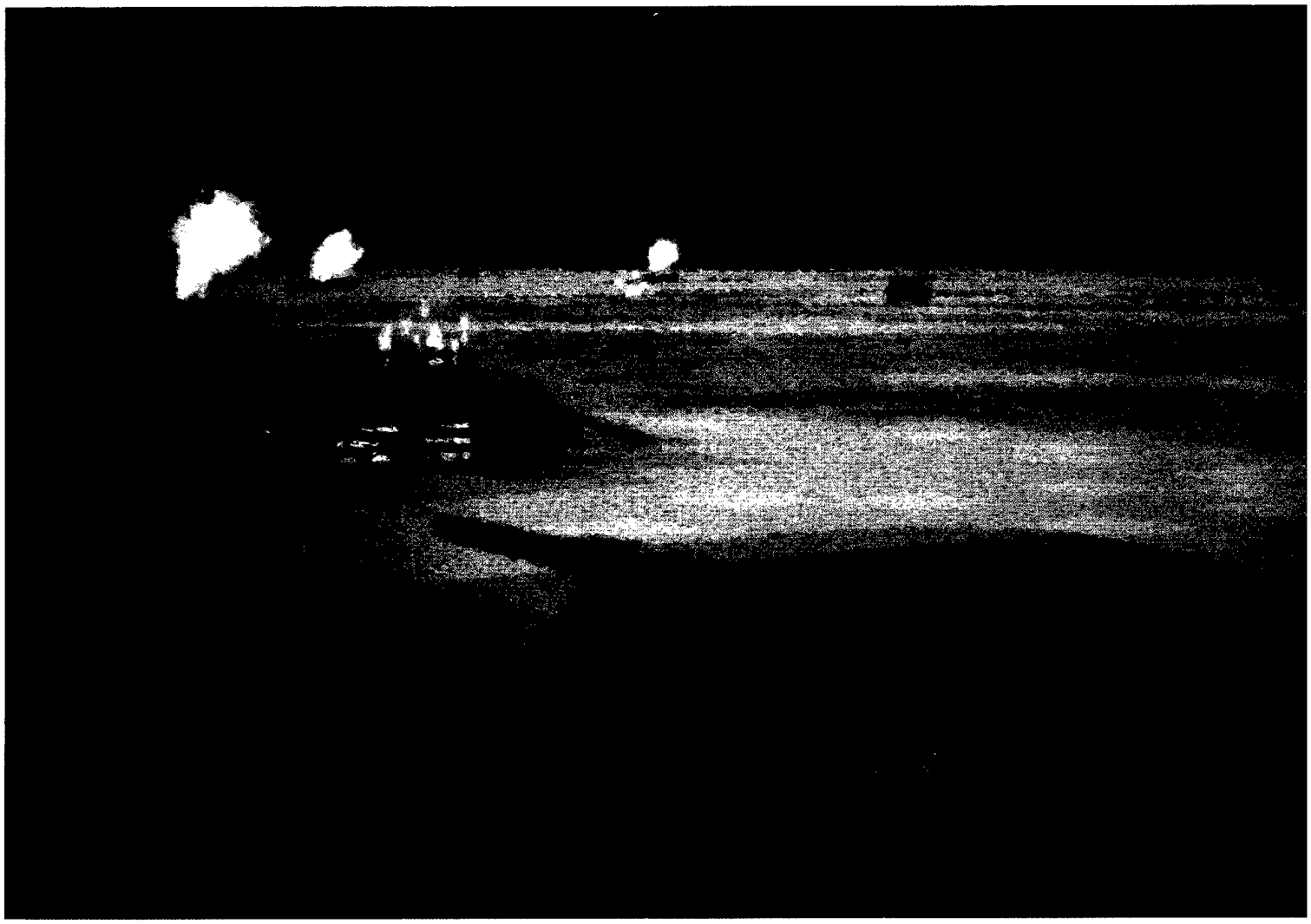
Modeling and Simulation

In the course of its normal work, IDA routinely engages in the construction, application, and assessment of models and simulations. The contexts in which models and simulations have been applied at IDA include system concept evaluations, weapon and support system effectiveness assessments, system configuration determinations, force structure analyses, operational testing and evaluations, individual and collective training studies, and support of operational planning and rehearsals. Recent noteworthy applications of modeling and simulation by IDA have included their use in Congressionally mandated studies (e.g., the B-1, B-2, and V-22) and in support of Operations Desert Shield and Desert Storm. In addition, IDA is now supporting DARPA in operating an Advanced Distributed Simulation Technology node and in assessing the value of distributed simulation in various DoD applications.

Models and simulations are gaining even greater importance as recent advances in technology allow for more comprehensive interactions, cooperative processing by widely separated computers, detailed graphical displays and other features that improve the realism of modeled systems and that enhance the comprehensibility of outputs. Moreover, these same features allow models and simulations to complement, to an ever increasing degree, training exercises, operational tests, and other costly activities.

IDA's expertise in modeling and simulation is helping the DoD take advantage of these new technologies. Two specific activities involve assistance to the Defense Modeling and Simulation Office and the establishment within IDA of our own Simulation Center.

Recognizing a lack of standards and coordination in the development of models and simulations, the DoD established the Defense Modeling and Simulation Office in June 1991 to serve as a focal point for the Department-wide use of models and simulations. One of its first actions was to call on IDA to work with several other Federally Funded Research and Development Centers to assist in defining program objectives. IDA is taking the lead in the development of a modeling and simulation "Master Plan" that will set out a systematic framework for guiding DoD's modeling and simulation program and for



Collecting "73 Easting" battle data, IDA used distributed simulation to recreate what actually happened and what effect new weapons and tactics could have on similar battles.

coordinating the various defense modeling and simulation communities, both within and outside the Department of Defense.

The support provided by the FFRDCs is centered around the activities of a number of Working Groups; these Groups address key modeling and simulation areas such as interoperability and architectures, applications and methodology, modeling and simulation technology base, information support, and near-term demonstrations and experiments. IDA has representatives either leading or participating in most of these Working Groups, the output of which will help inform and structure the Master Plan.

Just as DoD as a whole must determine how to best exploit models and simulations, IDA itself is addressing how to utilize new modeling and simulation technology, and how our staff should interact with the modeling and simulation community at large. The establishment in the late 1980s of IDA's Advanced Simulation Program was the most significant institutional response to these questions. The past two years have seen growth in this program, as well as the establishment of the DARPA-sponsored IDA Simulation Center. This facility is IDA's link with DARPA's Advanced Distributed Simulation Technology network.

This technology, pioneered in the Simulator Network (SIMNET) program, allows individuals in tank, aircraft, and other types of simulators to engage in real-time, large-scale simulated combat against similarly equipped enemy forces. Hundreds of simulators, located at many different sites, can fight on a common terrain in the same battle. The IDA Simulation Center provides a number of capabilities. In the short term, the Center enables IDA to conduct experiments using distributed simulation technology to support a variety of analytical efforts. Over the longer term, IDA will be exploring how the distributed simulation concept can be extended to provide linkage with operational training such as that conducted at the National Training Center, on the one hand, and analytical models such as we have used over the years in support of studies, on the other hand. The objective is to provide greater insights into the nature of warfare, and the value of systems and units, than could be obtained by linked simulators, operational training, or analytical models alone.

One recent IDA effort examined the applicability of SIMNET to the analysis of wide area mines—mines that have a radius of effect much greater than that of conventional mines. This study identified the issues to be addressed regarding wide area mines, the capabilities of SIMNET to represent mine-tank interactions, and the steps needed to implement a capability to evaluate wide area mines within SIMNET.

Another experiment in which IDA is participating, under DARPA sponsorship, is the reconstruction of the "73 Easting" tank battle that took place during Operation Desert Storm. Through examination of battle records and interviews with participants, a reconstruction has been created using distributed simulation technology. The simulation allows analysts and commanders to view the action on large screen displays from a variety of perspectives. By watching the battle unfold, it is possible to review the effectiveness of the actions taken, to assess implications for crew training and, by restaging the battle using alternative tactics, to investigate the implications of revised doctrines for armored warfare.

Also for DARPA, we are beginning to examine the applicability of distributed simulation to the training of reserve and National Guard forces. Reserve units are distributed around the country and generally have limited opportunity to interact on a large scale with active forces and other reserve units. By providing them access to distributed simulation of the SIMNET variety, these units could engage in relatively large-scale exercises and thereby possibly improve their readiness. Through the Simulation Center, IDA is helping to design and monitor tests associated with this activity.

The IDA Advanced Simulation Program also funds internal research to enhance our ability to assist the DoD more effectively. Recently, we began an experiment in distributed processing. As with many organizations, IDA has numerous computer resources connected through a variety of networks. Because computers tend to be associated with particular analysts, there are times when some computer resources are not fully utilized, while others are overloaded. A team of IDA staff is developing a suite of tools to allow the logical consolidation of physically distributed computer and storage resources. Because these tools incorporate a fault tolerant approach, they represent a technical

advance over similar efforts elsewhere. When implemented, they will significantly improve the ability of our staff to undertake computer-intensive analyses that require many runs of large models or that have extensive data reduction requirements.

The scope of modeling and simulation at IDA is therefore expanding. As we continue to build upon the modeling skills we have always maintained to support our analyses, we are also developing the expertise needed to help the DoD make the best use of advanced modeling and simulation technology in improving military capabilities.

Test and Evaluation of Defense Systems

IDA has supported the Office of the Secretary of Defense in test and evaluation of weapon systems since 1956. Our work in this area received new emphasis in 1985 with the creation of the Office of the Director, Operational Test and Evaluation (DOT&E). Reliance on IDA's technical and analytical support was broadened again in 1990 because of our freedom from Service-related and commercial conflicts of interest. IDA now provides test and evaluation support to more than 100 acquisition programs covering conventional land, naval, and air warfare systems; strategic systems, both offensive and defensive; space systems; and electronic combat and C^3 systems. In a complementary test and evaluation activity, IDA also supports the Director, Live Fire Testing.

Support for Operational Test and Evaluation

For specific weapon systems, IDA performs two major tasks as well as lesser but related ones. The first task consists of defining the necessary elements of a comprehensive operational test and evaluation program, and identifying alternative OT&E programs that might be conducted under given schedule and resource constraints. Our analyses cover all aspects of OT&E, including critical operational issues, test conditions and objectives, test methodologies, threat replication and potential wartime scenarios, measures of performance, potential use of simulations or models, and resource requirements. IDA's analyses are updated periodically to incorporate new information available at successive decision milestones. The analytic results of this process are designed to support DOT&E in evaluating the adequacy of OT&E plans prepared by the Services for determining the operational effectiveness and suitability of systems.

The second major IDA task consists of analyses in support of DOT&E's assessment, prior to a production decision, of the adequacy of the Service-conducted operational test and evaluation, and of the effectiveness and suitability of the system that is emerging from the development process. This aspect of our work requires a substantial presence in the field, with IDA analysts on site to observe test conditions and methods. Independent IDA analyses of test results and related information are designed to assist the DOT&E in the preparation of his

Beyond Low Rate Initial Production reports to the Secretary of Defense and the Congress.

Land Warfare Systems

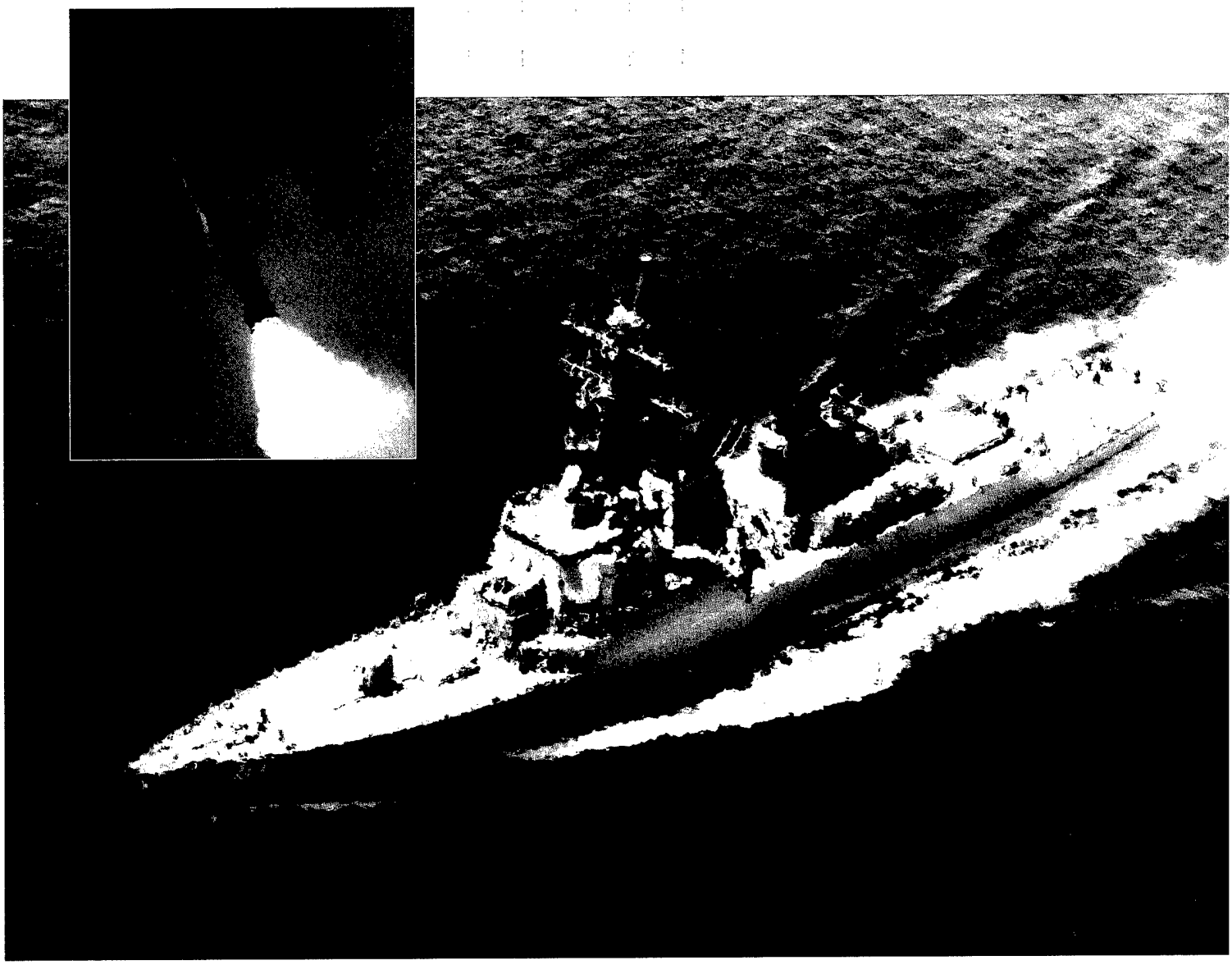
IDA's land warfare support to DOT&E has involved aviation systems, air defense, armored combat vehicles, fire support, anti-armor missiles, and directed energy weapon systems. Tasks performed during the past year have included the development of comprehensive test and evaluation plans and options for the OT&E of major ongoing acquisition programs, and the analysis of completed tests.

IDA's OT&E concept paper for the Light Helicopter (LH) identified major operational evaluation issues, a test concept to address those issues, and the critical test resources needed to support the proposed test concept. The paper, which was distributed to the Army operational test community by DOT&E, has had a considerable effect on early test planning for the LH OT&E, particularly concerning the scale of the field tests and the associated support resources. Similar concept papers are being developed for the Longbow Apache, Stingray, and Advanced Antitank Weapon System—Medium.

Evaluation plans, which provide the framework for DOT&E's independent evaluations as well as a basis for the review of the Army's detailed test planning, were developed for the Forward Area Air Defense Ground Based Sensor and Command and Control system, and the follow-on test and evaluation of the Paladin Howitzer. Independent analyses of completed tests were prepared for the AH-64 Air-to-Air Stinger Operational test, the Family of Medium Tactical Vehicles early user test, the Line-of-Sight Forward (Heavy) operational test, and the Advanced Antitank Weapon System—Medium baseline test.

Naval Warfare Systems

IDA's naval warfare tasks have supported acquisition programs for ships and aircraft, sensors and combat systems (sonars, radars, etc.), and weapons (torpedoes, missiles, etc.). The SEAWOLF submarine, the DDG-51 guided missile destroyer, and the Mk-50 torpedo were the subjects of major analyses in this reporting period.



IDA helps define the necessary elements of comprehensive test programs for a full range of new systems.

Our reviews and analyses of the Navy's SEAWOLF program illustrate IDA's contribution in planning for tests of naval systems. We reviewed the Navy's Early Operational Assessment to identify issues that should be covered during operational testing, and called attention to the importance of torpedo performance in the presence of threat countermeasures. Also, IDA monitored testing of the Improved SSN 688 class with the AN/BSY-1, and identified weaknesses in threat replication for these tests that could have affected the OT&E of SEAWOLF. IDA also identified potential improvements in the test ranges. The results of IDA's analyses indicated to DOT&E the need for testable, end-to-end performance measures for any new submarine.

Air and Electronic Warfare Systems

IDA's air warfare support to DOT&E has covered aircraft, air-to-air weapons, and electronic warfare systems. Among aircraft programs, a substantial effort was devoted this year to the Advanced Tactical Fighter (ATF). The advanced capabilities planned for this aircraft, such as stealth and supersonic cruise, increase the importance and challenge of devising a thorough test and evaluation program. IDA has identified the information elements that a comprehensive test program should yield, and has examined proposals to complement field testing through man-in-the-loop simulation and computer modeling. Although Service-developed simulations and models can provide much information that for safety and other reasons cannot be obtained from field tests, mock combat at U.S. Air Combat Maneuvering Ranges can provide insights into other performance factors and a degree of realism that cannot be obtained from simulators and models. Accordingly, IDA has recommended increased emphasis on open-air testing. We also have examined the resources allocated to testing and identified apparent shortfalls in the funding of ground facilities needed to test realistically the ATF's sensors, avionics, and electronic warfare systems in the configuration in which they will actually be installed in the aircraft.

Command, Control and Communications (C^3 Systems)

IDA's support to DOT&E in the C^3 area has included work on

communications, command and control (C^3), automated data processing (ADP), and sensor systems. In the communications area, the Single Channel Ground and Airborne Radio System (SINCGARS) received considerable emphasis in 1991. Because of the requirement for large quantities of radios, second source radios are being developed and are scheduled to undergo operational testing in FY 1992. IDA's effort has focused on ensuring that operational testing is adequate to resolve outstanding issues, and to demonstrate that the second source radio is operationally effective and suitable for production. IDA's support for C^2 and ADP programs has focused on the Army Tactical Command and Control System (ATCCS) and Automated Emergency-Action-Message Processing and Dissemination System (AEPDS). The ATCCS effort has focused on how to measure operational effectiveness of this $30 billion system in relation to the current manual baseline system. The AEPDS effort has focused on how to minimize risks for a program with a highly compressed schedule, while ensuring that testing will be related to the users' mission rather than to technical functions alone.

Strategic and Space Systems

IDA has performed analyses related to the full set of strategic offensive systems under DOT&E's oversight. Primary among these have been analyses of the B-2 bomber and its associated subsystems, the Tomahawk family of nuclear and conventional cruise missiles, and the Advanced Cruise Missile (ACM). Work has also been performed on the Peacekeeper Rail Garrison missile, the Small ICBM, the Titan IV launch system, and the SRAM II short-range attack missile.

IDA has been active in the test and evaluation of several major space systems for command and control, surveillance, communications, and navigation. The Cheyenne Mountain Upgrade (CMU) is a good example of our work in this area. The Cheyenne Mountain Complex is the central element of the North American Aerospace Command's system for early warning of strategic attack. The CMU program aims at replacing or upgrading every major command, processing, and display system in the complex. We have identified key integration phases of the Upgrade at which incremental end-to-end tests should be performed

and the critical interfaces that should be tested. For each such end-to-end test, we have developed a test concept to identify test objectives, measures of effectiveness, and sources of data, and based on these factors we have identified critical test resources needed to conduct testing, such as validated intelligence scenarios, threat simulations, and sensor message generators. By comparing needed resources with those provided in existing test plans, IDA has been able to identify several shortfalls which subsequently have been corrected by the appropriate DoD agencies.

Support for Live Fire Testing

Live Fire Testing (LFT) addresses the vulnerability of U.S. systems and the lethality of our missiles and munitions. For U.S. systems, specific attention is given to crew survivability. During the past year, we have been involved with more than 30 LFT programs in various stages of acquisition. Independent evaluations have been provided for the Forward Area Air Defense System Line of Sight-Forward-Heavy, the Army Tactical Missile System, the Advanced Medium Range Air-to-Air Missile, the C-17 transport aircraft, and the Mk-50 torpedo. Analyses bearing on plans for future tests of the M109-A6 Howitzer, the C-15 transport aircraft, and the DDG-51 guided missile destroyer also were conducted this year.

IDA's support of naval warfare systems included a strategy for the live fire testing of surface ships. While live fire T&E is required by legislative direction for all major systems undergoing acquisition, the Congressional language emphasizes full-up testing of full-scale, combat-configured systems, fired upon by likely threat weapons. IDA was tasked to identify and evaluate feasible and practical strategies for live fire testing of the DDG-51 that would be responsive to the spirit of the legislation. IDA identified issues, described in detail the elements of a live fire T&E program that would address the issues, and identified the benefits, costs, and risks associated with such a program. IDA also identified additional options for the live fire testing of future surface ships, such as the LX landing craft.

Support for Operations Desert Shield and Desert Storm

Much of IDA's work is done over a time period that allows for comprehensive data gathering and analysis, and thorough review. Occasionally, however, events demand a more immediate response. In these cases, IDA expertise developed during longer term studies can be brought to bear quickly to provide the Defense Department needed analytic support. The Persian Gulf conflict was just such an event, requiring the redirection of a number of IDA research efforts and personnel to assist in planning for the coalition war effort.

Previous IDA analyses of Southwest Asian scenarios—using the TACWAR theater model—provided a springboard for analytical support to the Joint Staff during both Desert Shield and Desert Storm. Shortly after the invasion of Kuwait, we were asked to analyze the implications of alternative force levels, deployments, and tactics in the Persian Gulf theater. Particular emphasis was placed on examining potential combat losses so that requirements for sustaining the force could be estimated. Intelligence and operational data were updated almost daily during the late summer and fall of 1990, model runs conducted, and briefings for the Joint Staff prepared. The Joint Staff incorporated the results of these analyses into their assessments of force capabilities, which, in turn, supported briefings to key national decision makers.

In addition to conventional warfare, the possible use of Iraqi chemical weapons had to be considered in the planning process. In earlier studies, IDA had developed a unique capability to estimate usage rates for chemical defensive equipment in a variety of theaters and scenarios. Within two weeks of Iraq's invasion of Kuwait, IDA was asked to project usage rates for some 15 items such as chemical suits, masks, gloves and atropine injectors. These estimates were updated periodically as the coalition buildup progressed. In-theater stocks of some chemical defensive equipment were adjusted as a result of this work.

In addition to equipment assessments, IDA analyzed the potential effects of chemical weapons on the military campaign. Again using the TACWAR model, IDA examined campaigns with and without chemical weapons, under various assumptions about ground force deployments and tactical aircraft allocations. The analyses pointed to

how and where the impact of chemical weapons would be greatest. On balance, this work indicated that Iraqi chemical weapons—had they been used—would have had little effect on the overall outcome of the conflict.

IDA also contributed to mobilization planning during the crisis. Drawing on previous work related to the Joint Industrial Mobilization Planning Process and the Graduated Mobilization Response Process, IDA was able to help OSD and the Joint Staff develop quantitative estimates both of the requirements—for materiel, lift, and personnel—and of the time-phased availability of resources to meet those requirements. Fall-back options were identified when preferred resources could not be made available in time. IDA also participated in DoD planning sessions and assisted in examining ways to capitalize fully on host nation support, to expedite the delivery of German chemical agent detection systems, to substitute alternative supplies to compensate for various shortages in sustainability items, and to replenish materials lost and consumed.

Finally, IDA was a key member of the team established by the Defense Advanced Research Projects Agency to develop an advanced command facility to assist in operational planning for Desert Storm. This facility exploited advanced distributed simulation technology, digital communications, digitized maps, and several other technologies to provide information on the location of enemy forces. This unique system would allow operational planners to view simulated enemy forces on a three-dimensional digitized map of the actual terrain. The forces could be moved to alternative locations and engaged in simulated combat, if desired. IDA helped address key technical challenges, including the integration and updating of terrain data acquired from several sources, the tracking of the movement of forces over time, and the reliability of the new system itself. This equipment currently is being used to reconstruct and analyze in detail one of the battles of Desert Storm.

Since the conclusion of hostilities, IDA has been involved in the documentation of crisis and wartime activities, and in the assessment of lessons learned for the future. IDA has conducted this kind of analysis before, including assessments of the Falklands conflict, Operation Just

Cause, and the 1973 Middle East War. As in the past, the current efforts are intended to create an authoritative record of what happened in the Persian Gulf and to evaluate the implications for future situations that may involve quite different strategic and tactical settings.

In one such task, IDA is assisting the Under Secretary of Defense for Acquisition develop and implement a plan for the collection of technical data on the performance of U.S. systems in Operations Desert Shield and Desert Storm. This involves the identification of data requirements, the development and publishing of a collection plan, and the cataloging of all technical data collected by the Services and Defense Agencies. It took only six weeks, with IDA support, for OSD to disseminate both a comprehensive data collection plan and guidance to the Services for data reporting. The *Operations Desert Shield/Desert Storm Technical Data Directory* lists over 8000 data sources in a fully automated format to facilitate data searches by keyword, mission area, weapon system, and so forth. The *Directory* will serve for years as a key reference for analysts seeking access to combat data from the Gulf War.

IDA also has been asked to assess lessons learned for the acquisition of weapons systems. This effort calls for independent evaluation of the performance of major systems in the Persian Gulf, with an eye on plans for future acquisition programs. This task is in its initial phase, examining the air war and the performance of U.S. systems executing the major missions of the air campaign, including strategic targeting, defensive and offensive counter-air, battlefield air interdiction, and SCUD hunting, among others. Primary data sources, such as air tasking orders, flight logs, and aircraft video recordings will be emphasized in this comprehensive analysis.

Additional analyses are being performed for other offices. At the request of the Assistant Secretary of Defense for C^3I, IDA will be examining the impact of C^3 countermeasures; for EUCOM, which supplied a significant portion of their air, ground, and naval forces to the theater, IDA has documented their experiences and will be using this information to help them plan for future contingencies.

The military success of Operation Desert Storm rested upon decisions made over decades, both in the course of day-to-day business

and in the aftermath of military operations such as that in Grenada. Recognizing this, IDA is embarking on an internally funded study tracing the roots of the Desert Storm victory back in time to decisions made between the end of the Vietnam conflict and the commencement of hostilities in the Gulf. Among our goals—to illuminate the decision making process, and to provide guidance not only for future decision makers facing significant budget and force structure constraints but also for organizations such as IDA that provide the fundamental technical analyses by which defense decisions are made.

Large-Scale Information Systems

Timely information is the foundation of good decision making, whether that decision making concerns battlefield operations, the direction of systems developments, diagnoses of equipment failure, or the allocation of resources. It is vital that the Department of Defense gets the right information to the right people so as to operate as efficiently as possible. The spread of modern computers and communications systems allows increasingly large amounts of data to be assembled and disseminated—creating both new opportunities and new requirements for information management.

IDA is addressing two aspects of information management. The first is the management of large amounts of data consolidated in a single system. Through analyses ranging from identification of functional requirements to the development of expert systems and graphical presentation tools, IDA is helping agents and analysts in the Federal Bureau of Investigation make more efficient use of available information. The second aspect is the integration of heterogeneous, widely distributed information systems. Our work here not only addresses the technical aspects of this problem, but also helps frame the policies and standards that the DoD needs to manage information effectively.

Typical of the broad scope of these efforts is IDA's response to a request by the Defense Information Systems Agency to develop an architecture for Command and Control Information Systems (CCIS). The objective is to outline a technical approach for modernizing the Worldwide Military Command and Control System by the mid- to late-1990s. The proposed architecture emphasizes the use of distributed computing resources both within and among command centers and prescribes consistent interfaces for hardware and software. The approach would enhance the system's ability to accept advanced equipment and programs, facilitate the development of new functionality, eliminate communications bottlenecks, and minimize costs through a more efficient utilization of resources. Moreover, our analysts have found that the best networked computer systems for supporting military command and control would be similar in many ways to other, non-military information systems that support planning, decision making, and execution. Thus, the proposed architecture for

CCIS is based on commercial standards that could accommodate expected technology improvements over the next decade. Costs could be kept down by utilizing commercial, off-the-shelf products in much of the system.

In the IDA-defined architecture, functions now served by mainframe computers and terminals would be performed by local networks of servers and workstations with local networks tied together via gateways and a wide area network. For this "network of networks" approach, IDA also is identifying the relevant protocols and standards for data management and exchange, network services, user interface services, operating systems, security, and applications development. This approach, if accepted by DISA, will be used to guide the development of systems by commercial firms.

Command and control, of course, is not the only area where extensive communication among dispersed organizations is necessary. Increasingly, military systems are developed by teams of contractors that, to be efficient, must coordinate closely on product development and the design of manufacturing processes. Properly constructed engineering and manufacturing information systems can allow team members to share product and process information both within and among firms.

The need for close coordination among contractors is not unique to the defense industry. Information systems supporting defense contractors should be consistent with commercial approaches, to the extent possible. Unfortunately, although both government and industry are addressing pieces of the problem, these efforts often are conducted in isolation. Effective solutions require national and international strategies based on consensus and cooperation among users.

Recognizing the need for an organization that can pull together and integrate a variety of perhaps inharmonious views, IDA was asked to assist in forming a consensus among government, industry, and the academic community regarding requirements, capabilities, and available technology to build comprehensive information systems for contractor teams. This assessment has focused on interfaces, common ways of depicting products, process modeling languages, and communication

requirements. We are working closely with all parties to develop agreement on these matters which, we believe, could broaden demand for products and stimulate U.S. information systems suppliers, tool vendors, and integration houses to provide adaptable engineering and manufacturing information systems to meet both commercial and DoD needs.

In addition to facilitating information flow among distant entities, IDA also is examining the information required for the effective maintenance of individual, highly sophisticated weapon systems. Integration of many information-based resources is required for an efficient maintenance process, including built-in test facilities, automatic and intelligent test equipment, technical data and training aids. These resources, taken together, provide for the diagnosis and correction of faults and can account for about 50 percent of a weapon system's total life-cycle costs. IDA research in this area has identified ways to improve the integration of information for diagnostic testing, and several of our suggestions have been implemented by the Services. In addition, IDA has provided technical leadership in developing commercial standards in automatic testing and diagnostics for complex systems, from development through production to field use.

Information management can be a costly business, requiring new equipment, software and retraining of personnel. It is therefore necessary to understand the savings it offers if investment plans are to go forward. IDA has been conducting studies of these issues, as well.

In 1989, the Defense Management Review recommended improving the efficiency of DoD information systems by reexamining business information processing needs, data models, information systems, and the computing and communications infrastructure. These suggestions led to a far-reaching modernization project known as the Corporate Information Management Initiative, under the responsibility of the Director of Defense Information (DDI). Eight areas were identified for early review, including civilian payroll, civilian personnel, contract payment, and financial operations. At the request of the DDI, IDA has developed a methodology for calculating cost savings associated with improved business methods and the application of innovative

information technologies in each area. This method compares the costs of alternatives to the costs of doing business as it is done today, taking uncertainty and the time-value of money into account. The DDI now requires that estimates of cost savings, which must accompany proposals for improved business information systems, be computed and presented in a manner consistent with the IDA method. We also developed a prototype computer model to facilitate implementation. The model is in use at several hundred locations in the DoD. IDA continues to assist the DDI in applying the model, tailoring its design to lower levels of detail, relating savings to specific budgetary program elements and appropriation categories, allocating indirect costs, and enhancing the computer model itself.

In sum, improvements in information management can lead both to increases in operational effectiveness and reductions in the costs of the supporting infrastructure. Because of these potential benefits, the Defense Department and other government agencies are seeking to modernize their information management systems and to expand their coverage. IDA has been asked to assist in this work. We believe our support will become even more important in the future as new computing technologies create opportunities for further advancements while budget pressures accelerate the search for efficiencies.

Space Systems and Concepts

The value of space systems to U.S. national security has been evident for many years. Today, military forces rely heavily on the surveillance, communications, and navigation provided by satellite systems. IDA has long been involved with the analysis of space-related topics for sponsors in the Defense Department. More recently, new efforts have begun in support of the National Aeronautics and Space Administration.

Support for DoD

Fundamental to national security is the ability to detect and track ballistic missile launches and to determine their type, launch location, heading and projected impact area. For the Strategic Defense Initiative Organization (SDIO), IDA has provided scientific and technical analyses of ballistic missile plume signature phenomenology—plume signatures being the most important observable of a missile during its launch phase. The new emphasis on theater missile defense, driven in part by the success of the Defense Support Program Satellites and Patriot air defense system in Operation Desert Storm, has concentrated attention on the plume signatures of smaller tactical ballistic missiles, such as the Iraqi SCUD variants. For a successful theater defense in the future, satellites must be able to detect tactical missiles that have significantly dimmer signatures than strategic missiles. Thus the background clutter against which tactical missiles must be tracked becomes a very significant concern. The SDIO has asked IDA to evaluate the current state of knowledge of background clutter phenomenology and boost-phase missile tracking concepts. These studies will affect the requirements for the detection of tactical missile launches from space.

Under the joint sponsorship of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (C^3I) and the Director of Defense Research and Engineering, IDA has examined advanced concepts for space-based wide area surveillance. This analysis led to a conceptual design for a hybrid system that could be less costly and potentially more effective than either of the original proposals. As a result of the knowledge gained in this effort, IDA has been asked to work with both the Air Force and the Navy program

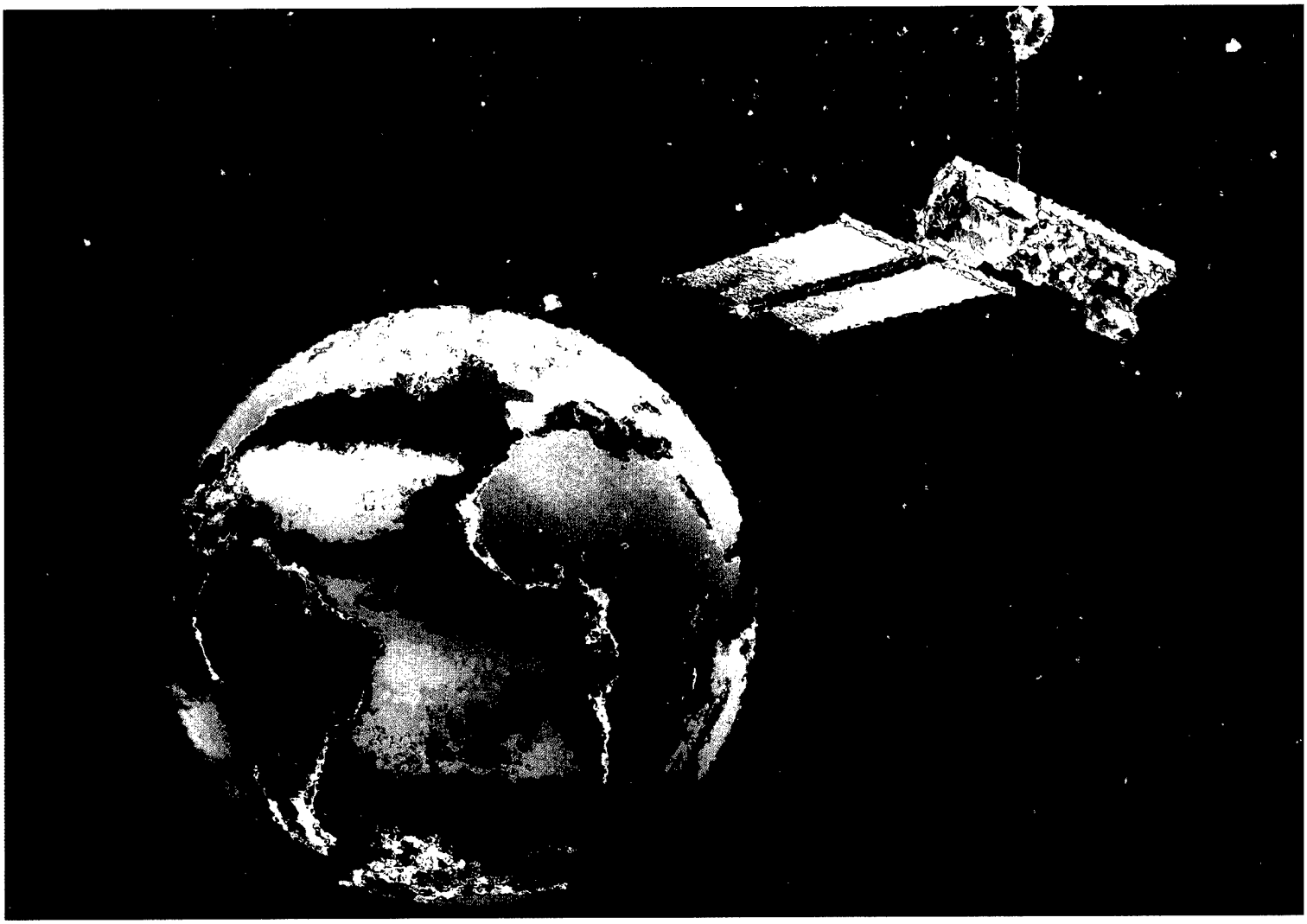
offices in conducting a Congressionally mandated assessment of the performance of alternative systems for space-based wide area surveillance of low-observable targets.

Satellites that provide warning of strategic attack must have sensors that function around the clock and meet extraordinarily high standards of reliability. As part of our support to the Assistant Secretary of Defense for C^3I, IDA is examining emerging sensor technologies that could both mitigate deficiencies in current systems and expand the set of targets that could be detected by space-based surveillance systems. Additionally, during the past year, IDA analyses for the Defense Information Systems Agency and the Joint Staff contributed significantly to the DoD long-range plan for wide area surveillance programs.

For DARPA, IDA has examined the capabilities offered by space-based navigation systems. Specifically, we have been researching the feasibility of using GPS—the Global Positioning System—for improving the precision guidance of a variety of advanced smart weapons. In addition to technology and systems questions, IDA has been at the forefront of estimating the costs and schedules associated with various space programs, ranging from the Brilliant Pebbles space-based defensive system to a variety of software development efforts.

Support for NASA

In December 1990, the Augustine Panel, formally known as the Advisory Committee on the Future of the U.S. Space Program, highlighted the value of independent analyses and assessments of NASA's current and future programs. It recommended that an independent group, reporting to the Administrator for NASA and his immediate staff, be established to provide analyses of system concepts and associated costs. In May 1991, NASA announced the creation of a new Systems Analysis and Concepts Office to be complemented by a Federally Funded Research and Development Center. IDA has been selected to provide that FFRDC support. In general, our role will be to augment NASA's efforts with technical and cost assessments and with independent analyses of alternative approaches to meet program



IDA's program for NASA includes the study of options for remote sensing of global change.

objectives. With a successful history of evaluating major government programs and broad expertise in space systems, IDA will provide a unique perspective that will assist NASA in balancing program objectives against overall U.S. goals. Our initial research involves studies and analyses in two areas:

Concepts for Near-Term Collection of Climate Change Data

Mission to Planet Earth is NASA's central contribution to the U.S. Global Change Research Program for understanding changes in the earth system, particularly those resulting from human activities. The Earth Observing System (EOS) is the major program in this effort, consisting of a space-based observing system, a data and information system, and a scientific research program. A key focus of the EOS is to gather data essential to understanding the nature of climate change. However, the missions in this program are not slated to begin until the end of this decade. With increasing concern over global warming, there are pressures to get some data earlier to support national policy decisions. NASA has asked IDA to identify cost-effective, near-term options that might provide more timely collection of critical data, and that could complement the planned EOS and related global change programs.

Future Orbital Transportation Needs

Future orbital transportation capabilities must be both responsive to the evolution of Space Station Freedom's research program and consistent with the Space Exploration Initiative. Although a number of unmanned orbital transfer vehicle concepts have been examined in the past, no comprehensive assessment of mission needs and system alternatives has been conducted recently. Further, the key technologies needed for the efficient implementation of such capabilities are not well defined. IDA currently is examining these and related issues with the intent of identifying promising unmanned orbital transportation system concepts.

Extended support for NASA is an important new initiative for IDA. It adds a challenging opportunity to continue IDA's dedication to quality analyses in support of major decisions affecting the allocation of national resources.

Observables and Sensors

The performance of the F-117 attack aircraft in the Persian Gulf highlighted the importance of "stealth" to military systems. IDA has been examining low observable systems and technologies over a number of years. These analyses run the gamut from phenomenology-based technology assessments to broader cost and operational effectiveness studies.

IDA also has been examining the other side of the observability issue—the ability of U.S. sensors to detect enemy systems. Over the years, this work has included assessments of technologies and systems for strategic and tactical applications utilizing radar, infrared (IR) and other sensing phenomenologies. This long-standing strength in the analyses of sensors, coupled with growing expertise in low observable systems, has led to increasing emphasis on these important subjects in IDA's research program.

One recent example is the Congressionally directed independent assessment of the performance of the B-2 aircraft. The first phase of this ongoing study examined the capability of the B-2 to penetrate future Soviet air defenses. This analysis incorporated the then-latest intelligence information and projections of future U.S. force capabilities and employment strategies. A computer model was developed to reflect the characteristics of low observable aircraft engaging various elements of a comprehensive air defense system. The study also assessed the performance of related systems, such as the B-1B bomber, the Air-Launched Cruise Missile and the stealthy Advanced Cruise Missile under a variety of postulated threats and operating conditions. This analysis described, in quantitative terms, the capability of the B-2 to carry out its nuclear mission and the B-2's relative contribution to the strength of future U.S. bomber forces.

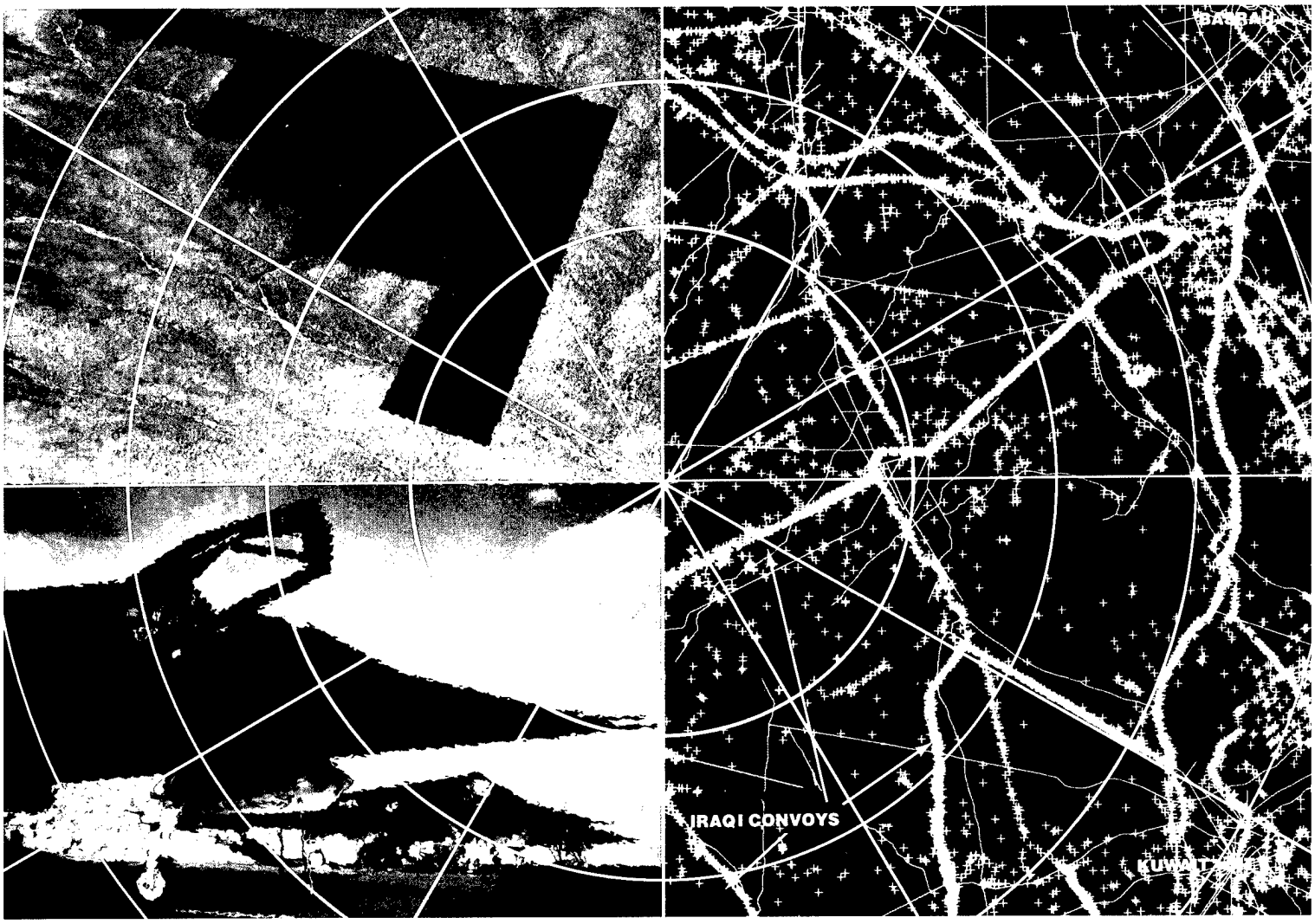
The Office of the Secretary of Defense likewise turned to IDA to lead a study of the performance of selected tactical warfare systems that incorporate low observable or counter low observable features. The first step will be a net technical assessment of U.S. and foreign technologies and systems. This project will evaluate the relative strengths and weaknesses of current and planned U.S. tactical systems, such as the F-117 and the F-22 advanced tactical fighter aircraft, and the Patriot and

Aegis surface-to-air missile systems. The study also will examine foreign low observable and counter low observable technologies and systems. The next step will be a more detailed examination of the contributions of alternative attack aircraft. For example, the performance of future Navy attack aircraft in a broad range of potential conflict scenarios will be estimated. Similar assessments will be conducted for potential follow-ons to the Air Force's F-111 and F-15E aircraft.

In the area of infrared low observables, IDA has been playing a leading role in the development of the technology itself, in addition to the assessment of associated performance and survivability implications. Recognizing the growing significance of the infrared signature—due to the appearance of advanced infrared acquisition and weapon systems, as well as the recent payoff of investments in radar low observable technology—DARPA turned to IDA to initiate and lead a program to develop a technology base for infrared low observables. This ongoing program is exploring all aspects of the infrared low observable problem, from theory to practical applications.

As weapon systems become more difficult to acquire and track—more stealthy—greater requirements are placed upon sensors. Not only must sensor systems detect targets at a militarily useful range, but also they must be incorporated into weapon or command and control systems that convey the information in a useful way either to human operators or to automated controllers. Here, too, IDA continues to analyze the technological and systems aspects of sensor phenomenology in a variety of physical domains and mission areas.

Building on long-standing expertise in IR technology, IDA is assisting in the review and direction of potential U.S. infrared search and track systems (IRSTs), and in the assessment of the capabilities of foreign IRSTs. The past years' work has emphasized IRSTs that autonomously detect and track targets, such as aircraft, using both thermal target emission and reflected sources for detection. These systems are becoming more important with the advent of stealthy aircraft and the proliferation of anti-radiation missiles, each of which decreases the utility of radars in some tactical situations. Understanding the capabilities of foreign and U.S. IRSTs is vital for assessing the



Analyses of low observable aircraft and advanced sensors have become increasingly important components of IDA's research program.

survivability of aircraft in many combat environments.

We also are examining advanced radar technologies. Over the past year, IDA has been helping the Balanced Technology Initiative Office in DDR&E explore the potential applications of ultra-wideband, or impulse, radar. This technology exploits recently developed, extremely fast, high-voltage switches to generate very short, high-power radar pulses. It combines the potential for superior range resolution with an ability to extract low-flying targets from a cluttered background. In addition to performing specific technical analyses in this area, IDA has been called upon to advise the Balanced Technology Initiative Office on the merits of analyses and recommendations offered by expert panels, technology proponents and contractors.

Automatic target recognition is a technology that employs computer processing of the outputs of one or more sensors to cue human operators to the approach of possible enemy systems. Except for very restricted applications, no automatic target recognition system is operational, but the potential of the technology to reduce the stress and workload on crews warrants careful examination. IDA continues its integrated research on automatic target recognition—research ranging from such technical issues as sensor fusion, which requires understanding of the interaction of target signatures with the environment, to human factors, which relates to the workload imposed upon operators.

Awareness of the human factor is important in IDA's work on the technological and operational aspects of night vision devices. These infrared or visual light amplification systems are commonly used by helicopter crews flying at night. Data have indicated that crews using night vision devices have a higher accident rate than crews not using them. IDA has identified a number of reasons for this phenomenon that are associated with the helmet-mounted display used on some current helicopters. The analyses are being used by the Services to develop ways to reduce accidents resulting from the use of night vision devices.

IDA & Its People

IDA maintains...
a high quality staff and technical capabilities across a broad range of matters of concern to its sponsors;

a stable interdisciplinary staff with broad and current knowledge and with continuing familiarity with the needs of its sponsors;

unquestioned objectivity, free from parochial interests, commercial ties, or other conflicts of interest;

trustworthy, privileged access to sensitive data, facilities, plans and related information, including proprietary data not normally available to non-government organizations.

The IDA mission is...
to address issues of urgent near-term and long-term interest in the planning and management of defense- and national security-related programs.

IDA provides...
studies, analyses, prototype software programs, analytical models, and other technical and analytical support.

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The Board of Trustees provides basic policy guidance to the corporation and its Officers. An Executive Committee is empowered to act for the Board between meetings. Additional committees include a Finance and Audit Committee and a Visiting Committee.

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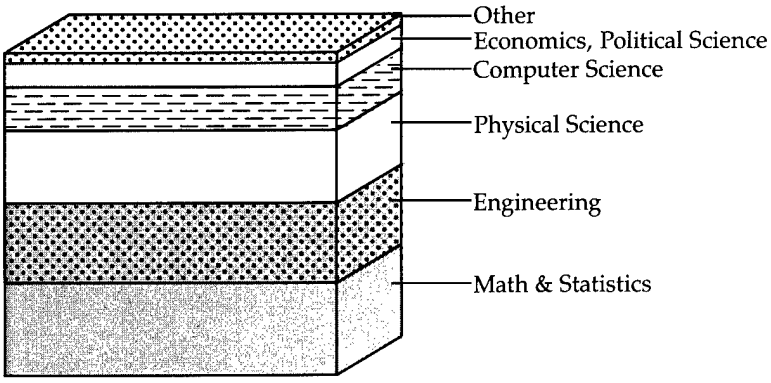
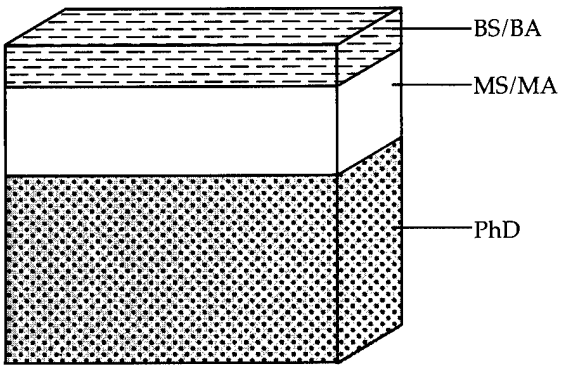
Staff

The Management and Staff of IDA comprise a cohesive unit, pooling intellect and education, working toward common goals. There are approximately 850 regular full time IDA employees, of whom approximately one-half are research professionals with backgrounds and experience covering every discipline in the physical, engineering, and analytical sciences, as well as the fields of international affairs, human factors, psychology and history. These men and women are outstanding quality performers of proven ability.

When particularly specialized skills and knowledge are needed to meet immediate requirements, IDA augments its professional staff by bringing in specialists from universities, industry and other research organizations. They add their expertise as periodic consultants, members of technical panels and working groups, or as staff members on temporary appointments.





Research Divisions

In order to carry out its work, IDA is divided into nine research divisions and four administrative directorates.

Science and Technology Division

Dr. Lemmuel L. Hill, Director

The Science and Technology Division (STD) conducts studies and analyses in which materials, space systems, surveillance and target acquisition, science and technology policy, and training, simulation and human factors are the key elements. The staff performs research generally involving either the investigation and modeling of scientific phenomena, or the technical characterization and evaluation of devices, systems, and equipment. These analyses provide guidance critical to research, development, testing and evaluation programs, acquisition decisions, and technology policy decisions. The Division's work contributes in an integral way to the identification of improvements in existing DoD programs, and provides a path for the identification of new research and development efforts.

Cost Analysis and Research Division

Dr. Stephen J. Balut, Director

The Cost Analysis and Research Division (CARD) collects, analyzes, and estimates the full life-cycle costs—from research through operating and support costs—of acquiring and operating specific defense systems and force components. The Division focuses its research program in three areas—systems, forces, and operating and support costs. Under systems, CARD studies defense contractor costs, cost and schedule estimating, acquisition experience case studies, test facilities and resource studies, and software costing. Under forces, the Division analyzes defense mission costing, force costing, and defense program costing. Under operating and support, CARD conducts studies of costs associated with maintaining readiness and sustainability, and manpower and personnel. Constantly working to create new or improved methodologies of cost estimation, frequently pushing the state-of-the-art, CARD's in-depth expertise allows it to serve as a valuable resource to other Divisions whose projects frequently involve cost issues.

System Evaluation Division

Dr. David L. Randall, Director

The System Evaluation Division (SED) provides systems analyses in the specific areas of strategic warfare, tactical warfare, and theater/tactical C^3. The Division also performs similar functions in certain non-DoD areas, such as for the Justice Department and NASA. SED provides substantive analyses of the potential performance and cost of systems that are proposed or in development, recommends ways to maximize system performance effectiveness while minimizing cost and vulnerability, and identifies the factors affecting choices among different systems for the same or related military tasks. System analysts address a range of considerations, such as the relationship of effectiveness to technical characteristics, deployment and operating modes, resources for system support, and the environment within which systems will operate.

Strategy, Forces and Resources Division

Dr. William J. Schultis, Director

The Strategy, Forces and Resources Division (SF&RD) provides assessments of economic and support issues related to defense, political and military studies that examine the global environment, and methodologies that are applied in large-scale force assessments. The Division's efforts are directed toward identifying fundamental changes in military strategy, operational doctrine, forces, and support arrangements as they relate to and influence Western security.

Operational Evaluation Division

Mr. Andre R. Barbeau, Director

The Operational Evaluation Division (OED) provides support to the Office of the Secretary of Defense in the test and evaluation of major new systems, and to the Unified and Specified Commands in developing, integrating, and improving the military planning process. OED performs analyses and evaluations of major military systems as they emerge from the development process. In accomplishing this task, the Division focuses its research in two essential areas—conducting

analyses that relate to the planning of test and evaluation programs to assure that they provide an adequate basis for successive acquisition decisions, and monitoring tests during actual execution, with subsequent analyses of results and evaluations of system effectiveness and suitability.

Computer and Software Engineering Division

Dr. Richard J. Ivanetich, Director

The Computer and Software Engineering Division's (CSED) principal mission is to conduct analyses of advanced computing systems and information technologies, both by themselves and in their explicit application to weapon, support, and C^3I systems. The research program is also directed toward the development of advanced computational techniques and their operational application in prototype systems. Currently, the Division divides its work into five categories—requirements and process analyses, assessments of computer technology programs, large-scale information system integration, system assessments, and prototype development.

Supercomputing Research Center

Dr. Paul B. Schneck, Director

The Supercomputing Research Center (SRC) provides research leading to increased computing capabilities for the Department of Defense orders of magnitude greater than that now commercially available. The work of the SRC focuses on design of algorithms, systems software, languages, and solutions to national security applications as well as on the design and construction of experimental parallel processors.

Center for Communications Research-Princeton

Dr. David M. Goldschmidt, Director

Center for Communications Research-La Jolla

Dr. Melvin M. Sweet, Director

The Centers for Communications Research (CCR) conduct mathematics research and study communications problems related to national security. Since its inception in 1958, CCR-Princeton has emphasized the study of mathematics and computer science. In 1978, the program was broadened to address speech research. The Center maintains expertise in the design and development of systems and applications software utilizing a supercomputer-based distributed computing environment. Close ties with the university community have helped keep CCR at the cutting edge of research. To facilitate interactions with researchers on the West Coast and to complement CCR-Princeton, IDA in 1989 established a Center in La Jolla, California, which became an independent IDA Division early in 1991.

Awards for Excellence

IDA's ability to fulfill its mission depends on its people — their intelligence, their experience, and their perseverance. To underscore the Institute's dedication to excellence at all levels of the organization, IDA annually presents awards to staff members whose work, either over time or on particular projects, has been exceptional.

The Andrew J. Goodpaster Award for Excellence in Research for 1991 was presented to Dr. Jeffrey H. Grotte of the Strategy, Forces & Resources Division. Dr. Grotte, a distinguished Operations Analyst, has made major contributions to defense research, particularly in the area of verification. His most recent work in arms control and verification affected the structuring of several treaties, particularly the START Treaty. He has also directed a number of international efforts for NATO related to verification.

The W. Y. Smith Award for Excellence, designed to recognize outstanding contributions by non-research professionals, was given to Ms. Patricia McCown, Purchasing Supervisor and Property Administrator, for her efforts in the successful automation of purchasing functions, and to Mr. Mark Kelley, a Programmer Analyst at the Center for Communications Research-Princeton, for his leadership of the programming and network administration group, for his lead role in integrating a new leading edge disk array system into the CRAY-2.

Three IDA President's Awards were presented to support staff members who typify the hard work, skill, and professional dedication that keeps IDA running. Mr. Paul Bublitz, a Senior Computer Technician at the Supercomputing Research Center, was honored for valued leadership in converting SRC from PCs to Sun workstations and for rebuilding the SRC classified library database in minimal time.

Mr. Tyrone Tutson and Mr. Jeff Capan of Information Services/Computer Services received a joint award for their teamwork and excellence associated with the installation, repair and upgrading of nearly 650 microcomputer systems during the Institute's relocation into its new Virginia facility.

Ms. Betty Pinna, Computer & Software Engineering Division, was honored for her consistently exceptional performance as Administrative Secretary. Ms. Pinna serves as Division troubleshooter, problem-solver, and 'expert' on the Sun test processing system.

A special note: In 1991, the Intelligence Community awarded the Intelligence Community Seal Medallion to IDA's Centers for Communications Research and the Supercomputing Research Center.

The IDA Colloquia

Ambassador R. James Woolsey, "CFE Treaty: Its Negotiation and Remaining Problems." R. James Woolsey serves with the rank of Ambassador as U.S. Representative to the Negotiation on Conventional Armed Forces in Europe (CFE). He brings to the job two decades of experience in U.S. security affairs, including service under four Administrations. Ambassador Woolsey served in the United States Army, being appointed Advisor to the U.S. Delegation to the SALT talks in both Helsinki and Vienna. He later became a member of the National Security Council Staff, then was named General Counsel of the Senate Armed Services Committee. He served in the Carter Administration as Under Secretary of the Navy and later was a Delegate at Large to the START and the NST talks in Geneva.

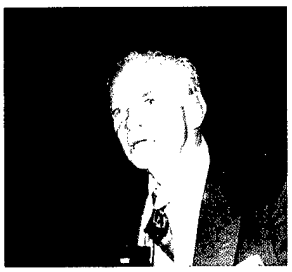
Dr. Roald Z. Sagdeev, "What Happened to the U.S.-Soviet Race in Space?" During the period 1973-1988, Dr. Sagdeev served as the Director of the Institute of Space Research in Moscow. He is a member of the USSR Academy of Sciences, the U.S. National Academy of Sciences, the Max Plank Society, the Royal Swedish Academy and the Royal Astronomical Society, UK. Dr. Sagdeev received the Order of Lenin for scientific achievements and the Lenin Prize for contributions to controlled fusion theory. He also was awarded the Hero of Socialist Labor Prize for directing the International Vega Project to encounter Halley's Comet and served as advisor to President Gorbachev

on Space and Arms Control at the summits in Washington and Moscow. Dr. Sagdeev is now a Distinguished Professor of Physics at the University of Maryland and Professor of Physics at the Moscow Physico-Technical Institute.

Admiral Bobby R. Inman, USN (Ret), "Gaining New Ground: Technology Priorities for America's Future." Admiral Inman was graduated from the National War College in 1972 and was selected for promotion to Rear Admiral in 1974, then to Vice Admiral in 1976. In February 1981, he was promoted to the rank of Admiral, the first Naval Intelligence Specialist to attain four star rank. He retired with the permanent rank of Admiral in 1982. During the period from 1974 to 1982, he served in tours as Director of Naval Intelligence, Vice Director of the Defense Intelligence Agency, Director of the National Security Agency, and Deputy Director of Central Intelligence. Admiral Inman is a member of several boards of directors; he serves in a volunteer status as a Director of the Council on Foreign Relations and the Center for Excellence in Education. He also serves as the Vice Chairman of the President's Foreign Intelligence Advisory Board.

Mr. Frank C. Carlucci, "Items of Interest—Worldly Affairs." Mr. Carlucci's experience in government services in the Executive Branch spans four U.S. Administrations of both Republican and Democratic Presidents. His appointments include Secretary of

Defense, Deputy Secretary of Defense, Assistant to the President for National Security Affairs, Deputy Director of Central Intelligence, Ambassador to Portugal, Under Secretary of the Department of Health, Education and Welfare, and Associate and then Deputy Director of the Office of Management and Budget. After leaving the Department of Defense, Mr. Carlucci became Vice Chairman of The Carlyle Group, a merchant bank in Washington, D. C.



Mr. Ben R. Rich, "Past and Future of Air Breathing Technology." In 1991, Mr. Rich retired as President of the "Skunk Works" of Lockheed Corporation after serving with that company since 1950. He currently is a consultant to both Lockheed and The Rand Corporation. Mr. Rich is a recognized expert in the aerodynamic, thermodynamic, propulsion and preliminary design aspects of the F-104, the U-2, the YF-12, and the SR-71 aircraft. He has earned international recognition for his work on these and other technologically sophisticated programs. In February of 1990, the National Aeronautical Association announced that Mr. Rich and the entire Lockheed/Air Force team had been awarded the most prestigious award in aviation, the 1989 Collier Trophy for the deployment and production of the F-117A Stealth fighter.

Mr. Norman R. Augustine, "Defense, Space, Commerce—An Industrial Overview." Mr. Augustine currently is

Chairman and CEO of the Martin Marietta Corporation. He has served in various senior positions in government, including Under Secretary of the Army and Assistant Secretary of the Army for Research and Development. He also has served as Chairman of the Defense Science Board. Mr. Augustine is a former President of the American Institute of Aeronautics and Astronautics, and is a Fellow of the Institute of Electrical and Electronics Engineers. He also is a member of the National Academy of Engineering. He served recently as Chairman of the Advisory Committee on the Future of the U.S. Space Program, and is the author of the popular book *Augustine's Laws,* which is widely read throughout the defense and government communities.

General Andrew J. Goodpaster, USA (Ret), "New Priorities for U.S. Security." General Goodpaster retired as President of IDA in 1985 and now serves as Chairman of the Atlantic Council of the United States. He also is the author of the book *For the Common Defense.* During his military service, General Goodpaster served as Defense Liaison Officer and Staff Secretary to President Eisenhower; Assistant to the Chairman, Joint Chiefs of Staff; Commandant of the National War College; Deputy Commander of U.S. Forces in Vietnam; Supreme Allied Commander, Europe; and Superintendent, U.S. Military Academy. He also assisted President Nixon in organizing his Administration for the conduct of foreign policy and international affairs. General Goodpaster has been awarded the U.S. Medal of Freedom, as well as many military decorations.

The Defense Science Study Group

The Defense Science Study Group (DSSG) is a program of education and study established in October 1985 by the Institute for Defense Analyses and supported by the Director of the Defense Advanced Research Projects Agency (DARPA). The goal of this program is to foster a long-term interest in national security issues among the future leaders of science and technology, an interest that would lead to participation in various advisory groups and a continuing involvement in programs of research of importance to the national security community. The objectives of the program are to identify some of the most talented young scientists and engineers, primarily in academia, convey to them an understanding and appreciation for the technical complexities of national security issues, and solicit from them new insights on such issues.

The DSSG is guided by a group of mentors who have distinguished careers in defense, industry or academia. Mentors advise IDA and DARPA on the conduct of the program, suggest problems of importance to study, assist the participants, review the technical work accomplished, and help identify candidates.

Participants are generally faculty members in the physical sciences, engineering or mathematics. They commit at least 20 days per year to this two-year program of education and study, for which they are paid a consulting fee plus expenses. Since a security clearance is required, participants must be U.S. citizens.

The DSSG two-year program is devoted primarily to education. Participants are given a broad exposure to national security issues, defense policy, defense-related research and development, manufacturing technology, and the systems, missions, operations and technical problems of the military Services. An understanding of the defense environment is provided through visits to defense and industrial facilities and presentations given by DoD program managers, technical specialists, and defense and industrial authorities.

Participants also receive briefings from senior members of many diverse organizations such as the Department of Defense, Department of Energy, Arms Control and Disarmament Agency, Central Intelligence Agency and National Security Agency. Site visits are made to defense

laboratories, the Strategic Air Command and the North American Aerospace Defense Command, among others, as well as bases responsible for satellite, missile, air defense, and submarine operations and training. Sites also include industrial facilities to gain a perspective on design and manufacturing technology for current and future systems.

During the second year, the educational part of the program continues and is augmented by individual or group study projects or the preparation of "thought pieces" on subjects related to national security. In some cases a participant might serve on a government panel, task force or study group. In 1991, DSSG members examined such diverse topics as solid rocket fuels, nuclear waste disposal, the duplication of natural structures in synthetic materials, and new approaches to the authorization and use control of conventional and nuclear weapons.

IDA conducts a rigorous process of nomination and referral in selecting participants for the DSSG. Candidates are identified from suggestions made by senior academics at major colleges and universities; by organizations such as DARPA, the National Science Foundation, the Office of Science and Technology Policy, and the Sloan Foundation; and by the DSSG alumni, current participants and mentors. The nominees are faculty members, generally in the 30-40 year age group. After an extensive reference process, and assuring candidate interest, IDA selects approximately 15 people to participate.

Because this program is an investment in the future, DARPA and IDA make every effort to assure that alumni are offered opportunities for continued involvement in areas related to national security. Such opportunities include serving as advisors, consultants or study group members to agencies, study boards or committees of the DoD associated with key technical problems of national importance.

Financial Report

Report of Independent Accountants

The Board of Trustees
Institute for Defense Analyses

We have audited the accompanying balance sheets of the Institute for Defense Analyses (the Institute), as of September 27, 1991 and September 28, 1990, and the related statements of revenue and expenses and change in general reserve and cash flows for the years then ended. These financial statements are the responsibility of the Institute's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of the Institute as of September 27, 1991 and September 28, 1990, and the results of its operations and its cash flows for the fiscal years then ended in conformity with generally accepted accounting principles.

Coopers & Lybrand

Washington, D.C.
December 12, 1991

Balance Sheets

September 27, 1991 and September 28, 1990

	1991	1990
Assets		
Current assets:		
Cash	$ 71,360	$ 442,448
Investments (Note 3)	4,584,918	11,500,000
Accounts receivable (Notes 2, 7 and 8)	17,499,197	11,292,349
Prepaid expenses	306,095	478,248
Total current assets	22,461,570	23,713,045
Bond issue costs—net	453,087	480,529
Property, plant and equipment—net (Notes 4, 8 and 9)	22,535,925	20,044,933
Other assets	4,310	132,475
Total assets	$45,454,892	$44,370,982
Liabilities		
Current liabilities:		
Current portion of bonds payable (Note 8)	$ 648,611	$ 648,611
Accounts payable and accrued expenses	4,529,664	6,189,534
Accrued annual leave	3,204,848	3,055,304
Accrued pension costs (Note 6)	180,381	179,022
Total current liabilities	8,563,504	10,072,471
Bonds payable (Note 8)	9,296,760	9,891,321
Commitments and contingencies (Notes 2, 5 and 8)		
General Reserve		
Unappropriated	27,594,628	24,407,190
Total liabilities and general reserve	$45,454,892	$44,370,982

The accompanying notes are an integral part of these financial statements.

Statements of Revenue and Expenses and Change in General Reserve

for the years ended September 27, 1991 and September 28, 1990

	1991	1990
Revenue:		
Contract revenue, including fixed fees of $4,850,660 and $5,277,493, respectively (Note 2)	$92,918,742	$95,218,605
Program expenses:		
Charged to U.S. Government contracts:		
Direct salaries	42,665,716	42,287,394
Other direct costs	22,317,383	26,984,372
Indirect costs	23,216,805	20,734,285
	88,199,904	90,006,051
Charged to Institute projects:		
Direct salaries	435,692	336,055
Other direct costs	987,330	1,257,082
Indirect costs	379,722	162,745
	1,802,744	1,755,882
Total program expenses	90,002,648	91,761,933
	2,916,094	3,456,672
Interest income:	271,344	333,889
Excess of revenue over program expenses	3,187,438	3,790,561
General reserve:		
Beginning of year	24,407,190	20,616,629
End of year	$27,594,628	$24,407,190

The accompanying notes are an integral part of these financial statements.

Statements of Cash Flows

for the years ended September 27, 1991 and September 28, 1990

	1991	1990
Cash flows from operating activities:		
Excess of revenue over program expenses	$ 3,187,438	$ 3,790,561
Adjustments to reconcile excess of revenue over program expenses to net cash provided by operating activities:		
Depreciation and amortization	1,654,736	1,213,626
Amortization of bond issue costs	27,443	29,971
Decrease (increase) in investments	6,915,082	(8,997,114)
Decrease (increase) in accounts receivable	(6,206,848)	8,840,036
Decrease in prepaid expenses	172,153	183,218
Decrease (increase) in other assets	128,165	(131,183)
Increase (decrease) in accounts payable and accrued expenses	(1,659,870)	339,725
Increase in accrued annual leave	149,543	443,777
Increase in accrued pension costs	1,359	12,986
Total adjustments	1,181,763	1,935,042
Net cash provided by operating activities	4,369,201	5,725,603
Cash flows from investing activities:		
Capital expenditures	(4,221,422)	(4,983,069)
Proceeds from sale of fixed assets	75,694	416,766
Net cash used in investing activities	(4,145,728)	(4,566,303)
Cash flows from financing activities:		
Payment of note payable	—	(393,113)
Principal payment of bonds	(594,561)	(648,610)
Cash used in financing activities	(594,561)	(1,041,723)
Net (decrease) increase in cash	(371,088)	117,577
Cash at beginning of year	442,448	324,871
Cash at end of year	$ 71,360	$ 442,448
Supplemental disclosure of cash flow information:		
Cash paid during the year for interest	$ 596,348	$ 696,000

The accompanying notes are an integral part of these financial statements.

Notes to Financial Statements

1. Accounting policies

The accounting policies of the Institute for Defense Analyses (the Institute) conform to generally accepted accounting principles. Significant policies followed are described below.

Reporting year

The Institute's fiscal year is the 52- or 53-week annual accounting period ending the last Friday in September. Accordingly, the Institute's current fiscal year ended September 27, 1991, and the prior fiscal year ended on September 28, 1990.

Contract revenue

All of the Institute's contracts are cost- plus-fixed-fee type contracts with agencies of the U.S. Government. Revenue from such contracts is recorded on the basis of direct cost, overhead and general and administrative expenses incurred, plus an allocable portion of the fixed fee. As soon as it has been determined that it is probable, a contract will result in a loss, and that loss can be reasonably estimated, the entire estimated loss is charged against income. In accordance with industry practice, accounts receivable relating to long-term contracts are classified as current assets, although an indeterminable portion of these amounts is not expected to be realized within one year. Billings in excess of costs and fees are included in accounts payable and accrued expenses.

Property, plant and equipment

Property, plant and equipment are carried at cost. The Institute provides for depreciation of plant and equipment on a straight-line basis over the following estimated useful lives:

Building and improvements	31-1/2 years
Computer equipment and furniture	5 to 10 years

Leasehold improvements are amortized on a straight-line basis over the lesser of the useful life of the improvement or the remaining term of the lease. Expenditures for maintenance and repairs are charged against income as incurred; betterments which increase the value or materially extend the life of the related assets are capitalized. When assets are sold or retired, the cost and accumulated depreciation are removed from the accounts and any gain or loss is included in income.

Research and development

Research and development expenditures for Institute-sponsored projects are expensed as incurred.

Bond issue costs

The costs associated with the issuance of bonds are capitalized and amortized on a straight- line basis over the life of the bonds (see Note 8).

Annual leave

Under the Institute's annual leave policy, employees are permitted to accumulate unused annual leave up to certain maximum amounts. The policy also provides for payment to employees of such unused amounts at termination or retirement. The Institute accrues annual leave as it is earned.

Income taxes

Under provisions of the Internal Revenue Code section 501(c)(3) and the applicable income tax regulations of the States of Virginia, Maryland, California, and New Jersey, the Institute is exempt from taxes on income other than unrelated business income. No provision for income taxes is required as of September 27, 1991, or September 28, 1990, since the Institute has no unrelated business income.

2. Contract revenue and receivables

All of the Institute's business is with departments or agencies of the U.S. Government and is subject to audit by the Government. The Institute is unable to bill certain costs and fees until the Government audits are completed and final settlement has been made. These costs and fees are included in unbilled accounts receivable.

The components of contract receivables at September 27, 1991, and September 28, 1990, are as follows:

	1991	1990
Billed receivables	$17,466,812	$ 9,962,526
Unbilled receivables	32,385	1,329,823
	$17,499,197	$11,292,349

Government audits have been completed and settled through September 30, 1987. The Institute believes that the effect of disallowed costs, if any, for the periods not yet audited or completed will have no material adverse effect on the financial statements.

3. Investments

Investments at September 27, 1991, and September 28, 1990, consisted of the following:

	1991	1990
Reverse Repurchase Agreements, 7.25% and 10% due on September 30, 1991 and 8.00% due on October 1, 1990	$ 4,134,918	$ 4,500,000
George Washington University Private Placement Note, 8.00%, due on October 1, 1990	—	2,500,000
George Washington University Private Placement Note, 8.125%, due on October 1, 1990	—	4,500,000
Time Deposit, 5.35%, due on June 22, 1992	450,000	—
	$ 4,584,918	$11,500,000

4. Property, plant and equipment

Property, plant and equipment at September 27, 1991, and September 28, 1990, are summarized as follows:

	1991	1990
Land	$ 245,720	$ 245,720
Building and improvements	13,930,528	13,986,279
Computer equipment and furniture	6,444,357	5,347,150
Leasehold improvements	7,498,434	5,331,010
Construction in progress	743,763	—
	28,862,802	24,910,159
Less accumulated depreciation and amortization	(6,326,877)	(4,865,226)
	$22,535,925	$20,044,933

5. Commitments

Minimum annual rental commitments under operating leases, principally for the rental of office space, with initial or remaining noncancelable terms of more than one year, are as follows:

Year ending September 30,	
1992	$ 6,299,510
1993	5,316,798
1994	5,316,798
1995	5,316,798
1996	5,316,798
Thereafter	28,783,048
	$56,349,750

The Institute has two lease agreements relating to the rental of an office building in Princeton, New Jersey. The first agreement expires in April 2002. The second agreement relates to an addition to that building and expires in April 2012. Both lease agreements are cancelable upon one year's notice. If the cancellation rights under these lease agreements were to be exercised, the Institute would be required to make a termination payment. As of September 27, 1991, the required termination payment is approximately $495,000.

The Institute has a 20-year lease agreement relating to the rental of an office building in Alexandria, Virginia. The lease term began January 20, 1982, and expires in January 2002. The lease may be terminated at any time and is subject to a termination penalty. The termination penalty, as of September 27, 1991, is approximately $1,432,000. The penalty payment is fully off-set under contractual agreements with the U.S. Government in the event of termination of the Institute's contract.

The Institute also leases additional space in an adjacent office building in Alexandria, Virginia. This lease term began in October 1990, and expires in January 2002. The lease may be terminated at any time and is subject to a termination penalty. The termination penalty, as of September 27, 1991, is approximately $3,037,000. The penalty payment is fully off-set under contractual agreements with the U.S. Government in the event of termination of the Institutes contract.

Payment for property taxes, including increases therein, and for other expenses attributable to the leased property is required by the terms of these leases.

Rent expense under operating leases for the years ended September 27, 1991, and September 28, 1990, was approximately $7,248,000 and $5,578,000, respectively.

6. Retirement plan

The Institute maintains a defined contribution retirement plan in which substantially all employees participate. Under the plan, the Institute contributes a fixed percentage of participating employees' base salary to an insurance company or a mutual fund. These contributions, in addition to employee contributions, are used to purchase annuities or units of participation in a mutual fund. Effective June 1, 1991, the Institute's retirement plan was modified to require a six-month waiting period for all new employees prior to participation in the plan. Retirement plan contributions on behalf of employees hired prior to June 1, 1991, vest immediately in the employees. Retirement plan contributions on behalf of new employees hired after June 1, 1991, vest fully in the employees after two years service. Retirement plan costs are funded as they accrue. The Institute's contributions under the plan were approximately $4,693,000 and $4,531,000 for the years ended September 27, 1991, and September 28, 1990, respectively.

7. Line-of-credit

The Institute has a line-of-credit agreement (the Agreement) with Sovran Bank (the Bank) for a maximum of $15,000,000. There was no outstanding balance under the Agreement as of September 27, 1991, or September 28, 1990. The line-of-credit bears interest at the lower of the Bank's prime rate less 50 basis points or the Federal Fund's rate plus 100 basis points. The line-of-credit interest rate is reset each Monday based upon the preceding Thursday's Federal Fund's rate. The Agreement expires on January 31, 1992. Interest expense under the line-of-credit was approximately $55,000 and $40,000 for the years ended September 27, 1991, and September 28, 1990, respectively. Under the terms of the Agreement, accounts receivable are pledged as collateral. The Institute is also required to maintain a positive working capital balance, certain debt-to-worth and current ratios and a general reserve balance not less than $16,000,000. The Institute was in compliance with these covenants as of September 27, 1991. The Institute expects to renew this Agreement under similar terms and conditions.

8. Supercomputing Research Center (SRC) facility

Land

The Institute has constructed a 117,000 square foot secured facility to house the SRC in Bowie, Maryland. On July 25, 1986, the Carley Capital Group and the University of Maryland Foundation, Inc. (the grantors) donated to the Institute, with certain restrictions, an approximate 14-acre parcel located within the University of Maryland Science and Technology Center in Prince George's County, Maryland. The land has been valued at $245,720, based on a notice of assessment dated December 8, 1986, from the Prince George's County Office of the Maryland State Department of Assessments and Taxation. In November 1988, the grantors and the Institute executed a Partial Release and Modification of Indenture Deed which removed all restrictions as to full conveyance of the land to the Institute.

Bonds payable

In order to finance construction of the SRC facility and the costs associated with the acquisition of the property, the Institute negotiated the issuance of tax-exempt Industrial Revenue Bonds (the Bonds) for $11,675,000 from Prince George's County, Maryland. The Bonds are seven-day, variable-rate demand bonds containing a ṗut© option permitting the bondholders to put the Bonds back to the Institute or its designee at the end of each seven-day period. The weighted-average interest rate of the Bonds was 4.9% for the year ended September 27, 1991, and 5.8% for the year ended September 28, 1990. The bonds are subject to mandatory redemption in annual principal payments of $648,611, beginning January 1, 1989, and ending January 1, 2007. The Institute is required to make monthly payments to a bond sinking fund, which is held by a bank, in order to fulfill the mandatory annual redemption payments. As of September 27, 1991, the Institute had deposited $1,729,629 into the bond sinking fund. In addition, the Institute is required to redeem the Bonds in whole promptly following the occurrence of any determination of taxability. The redemption price is 100% of the then-outstanding principal, plus a premium of 3% of the principal, plus all

unpaid interest accrued to the redemption date.

Costs associated with the issuance of the bonds have been capitalized and are being amortized over a 20-year period beginning January 1, 1987. Accumulated amortization was approximately $124,000 and $97,000 at September 27, 1991, and September 28, 1990, respectively.

Letter-of-credit

On December 16, 1986, the Institute entered into an agreement with Sovran Bank (the Bank), whereby the Bank made available to the Institute a letter-of-credit for $12,263,228, consisting of $11,675,000 for the principal amount of the Bonds, $237,978 for accrued interest and $350,250 for a taxability premium payable upon the occurrence of an event of taxability with respect to the Bonds. The letter-of-credit, which represents collateral for repayment of the Bonds, expires March 24, 1997. The Institute is required to reimburse the Bank, on demand, for all amounts paid by the Bank under the letter-of-credit, except for amounts paid by the Bank with respect to Bonds which have not been remarketed, provided that the Institute has been making the Bond amortization payments. The reimbursement obligation of the Institute, with respect to amounts paid by the Bank for Bonds which have not been remarketed, bears interest based on the Bank's prime rate. The letter-of- credit is collateralized by a first lien deed of trust granted by the Institute on the facility, including all land, buildings, improvements, furniture and equipment owned by the Institute and comprising the facility, and all leases and rents, accounts receivable, general intangibles, instruments and cash, and all proceeds therefrom, derived by the Institute from operation of the facility. For as long as the letter-of-credit is outstanding, the Institute is required to pay an annual fee equal to 7/8 of 1% of the maximum amount scheduled to be outstanding for any year or portion thereof. Under the terms of the letter-of-credit, the Institute is required to maintain a minimum net worth of $7,000,000. The Institute was in compliance with this covenant as of September 27, 1991.

9. La Jolla Center for Communication Research

In September 1991, the Institute entered into several contracts relating to the acquisition of a 55-year ground lease from the City of San Diego, development of site improvements and the construction of a secure facility for the Institute's Center for Communications Research in La Jolla (CCR-L). The Institute obtained a loan from Union Bank of San Diego (the Bank) in the amount of $5,250,000 in order to finance acquisition of the ground lease, and the costs, including interest, of constructing the CCR-L facility along with the necessary site improvements. The construction loan has a term of 15 months and bears interest at the Bank's rate plus 125 basis points. Interest is computed each month and is added to the outstanding balance of the principal. All outstanding principal and accrued interest are required to be paid upon the earlier of the expiration of the loan term or conveyance of the facility and the underlying ground lease to a third-party. As of September 27, 1991, no borrowings had been advanced from the Bank to the Institute. Subsequent to year-end, the Institute was required to pay $1,200,000 to the City of San Diego for the ground lease. These funds were advanced under the construction loan.

The Institute has executed a contract with the WesTerra Development Corporation (WesTerra), the former developer of the ground lease site, assuming all of WesTerra's rights and obligations with regard to the improvement of the site and the construction of the CCR-L facility. The Institute has recorded construction-in-progress costs of approximately $744,000 arising in part from the assumption of WesTerra's obligations to third-parties.

Under the terms of IDA's contract with WesTerra, WesTerra has the right, upon completion and occupancy of the CCR-L facility, to purchase the building and the underlying ground lease for an amount equal to all actual construction costs incurred. If WesTerra exercises the option, the building will be leased back to IDA.

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